ECOLOGICAL STUDIES IN THE BAYS AND OTHER WATERWAYS NEAR LITTLE EGG INLET AND IN THE OCEAN IN THE VICINITY OF THE PROPOSED SITE FOR THE ATLANTIC GENERATING STATON, NEW JERSEY

Progress Report for the Period January — December 1972
PART ONE

by
David L. Thomas, Ph.D. and Charles B. Milstein, M. S.

For
PUBLIC SERVICE ELECTRIC AND GAS COMPANY

Ichthyological Associates, Inc.
July 1973

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July 1973

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INTRODUCTION

In September, 1971, Ichthyological Associates began an ecological study of ocean sites off Long Beach Island and Little Egg Inlet, New Jersey for Public Service Electric and Gas Company.

A report was issued by Ichthyological Associates (1972) entitled "Ecological considerations for ocean sites off New Jersey for proposed nuclear generating stations." Part One reported on ecological data pertinent to the New Jersey Coast in the vicinity of the plant sites (Thomas et al., 1972). Part Two discussed the problems and made predictions regarding possible power plants for this area (Raney, 1972).

Some biological collections were made from October through December, 1971. In January, 1972, a more thorough sampling program was begun for fishes and invertebrates from Island Beach State Park to Atlantic City, New Jersey (Figs. 1, 2, and 3).

After March 1, 1972, collections were restricted to the vicinity of the proposed Site 8 and extended from Manahawkin Causeway at Long Beach Island to Atlantic City. From March through August the scope of the study was enlarged. By September, 22 biologists were studying most components of the marine ecosystem.

During 1972, sampling gear and techniques were developed and modified for maximum efficiency. Regular sampling stations were established and quantitative data were obtained when possible.

The first objective of the program was to identify the biota. Next, biological information from both the ocean and bays was collated. An attempt was made to study most of the types of organisms present because all are interrelated through the food chain. However, emphasis was placed on important commercial and sport species.

Because organisms vary spatially and temporally, it is necessary to study them not only throughout the year but over an extended period of time. This study includes both the ocean and estuaries because of the motile nature of organisms, and because of the importance of estuaries to coastal species.

This report covers the 1972 sampling program. For each study, the sampling schedule, materials and methods, and results are recorded and discussed. All studies will be maintained or expanded in 1973 in order to more fully describe and define local populations.

SUMMARY

1. In September, 1971, Ichthyological Associates began an ecological study of ocean sites off Long Beach Island and Little Egg Inlet, New Jersey for Public Service Electric and Gas Company.

2. In January, 1972, a more thorough sampling program was begun for fishes and invertebrates from Manahawkin Causeway at Long Beach Island to Atlantic City, New Jersey in the vicinity of Ocean Site 8 (hereafter called Site) off Little Egg Inlet.

3. This report gives the results of and discusses the 1972 sampling program.

4. Physicochemical parameters were recorded with each collection.

a. Ocean water temperature at the Site was lowest in February and March (2.5 C); it increased about 5 C a month through July (21.5 C). During June, July, and August bottom temperature averaged about 4 C lower than the surface temperature.

b. Differences between bay and ocean temperatures were greatest in the spring and early summer, and least during late summer and fall. The highest mean temperatures occurred during the last two weeks in July. They were 29.7 C in the Mullica River, 28.7 C in Great Bay, and 22.6 C at the Site.

c. Mean salinities for half-month periods ranged from 27.7 ppt to 31.5 ppt at the Site, 16.2 ppt to 26.3 ppt in Great Bay, and 3.5 to 19.2 ppt in the Mullica River.

d. Dissolved oxygen at the Site was greatest in winter and least during summer. Lowest dissolved oxygen occurred in August when the surface values averaged 7.6 ppm and bottom values averaged 5.2 ppm.

5. Sediment samples were taken and the sediments of the area described.

6. Fishes were collected primarily by seine, trawl, gill net, and lobster pot.

a. A total of 123 species of fish representing 57 families was collected in 1972.

b. A total of more than 326,000 juvenile and adult fishes was collected during 1972 by all methods combined. The most specimens and species were taken in the summer and the least during the winter.

c. Fifty-one species were represented by 100 or more specimens in our collections for the year and discussed. The first four species by numerical abundance were the Atlantic silverside, bay anchovy, striped killifish, and mummichog. They comprised 82% of all specimens taken during 1972.

7. Fishes of the shore zone were sampled at selected stations once every two weeks; several stations were sampled both during the day and night.

a. More than 208,500 fish of 74 species were collected in small seines. The greatest number of species (62) was taken in summer while the fewest species (25) were taken in winter.

b. The five most common species taken in small seines were the Atlantic silverside, striped killifish, mummichog, banded killifish, and sheepshead minnow.

c. The catch of fishes by seine was analyzed by season and by habitat. Most areas had a higher species diversity in the spring. The Mullica River had the highest species diversity followed by Great Bay, Little Egg Harbor, Brigantine and Absecon inlets, Long Beach Island ocean stations, Brigantine waterways, and Brigantine ocean stations.

d. More than 17,967 specimens of 66 species were collected with a 250-ft beach seine.

e. Most specimens collected by 250-ft beach seine were adults or large juveniles, while most specimens taken by small seines were juveniles except for small adult forage species. The species composition taken in beach seine collections was markedly different from that in small seine collections.

8. A total of 161 collections was made with a 25-ft trawl in the vicinity of the Site.

a. A total of 69 species, more than 53,554 specimens, and 332.6 specimens per collection (N/Coll.) were taken.

b. The first 10 species (89.6% of all specimens) ranked by numerical abundance were the bay anchovy (66.2%), red hake, silver hake, spotted hake, weakfish, American sand lance, windowpane flounder, butterfish, alewife, and northern searobin.

c. The first 10 species ranked by their frequency of occurrence (F), that is, the number of hauls in which they were taken, were the windowpane flounder, red hake, bay anchovy, spotted hake, winter flounder, northern searobin, smallmouth flounder, silver hake, little skate, and butterfish.

d. Number of specimens per collection (N/Coll.) declined markedly from inshore waters in depths of 5 to 19 ft to deeper seaward areas in depths of 40 to 69 ft. It was substantially lower on the Ridge than it was at depths of 20 to 39 ft and landward. It was greater than that at depths of 40 to 59 ft and seaward.

e. The bay anchovy dominated catches made in depths from 5 to 39 ft and on the Ridge; their numbers decreased in depths from 40 to 59 ft. Red hake, spotted hake, silver hake, and the alewife were common to abundant throughout the depths sampled except on the Ridge. Windowpane flounder and northern searobin were numerous in depths from 20 to 59 ft. Most specimens of the American sand lance (99%) were taken on the Ridge. The weakfish was most numerous in depths from 5 to 39 ft and on the Ridge. The butterfish was common in the depths sampled and on the Ridge.

9. Bottom collections with a 16-ft trawl were taken in the bays and waterways of the study area beginning on 22 February 1972.

a. More than 45,088 specimens of 64 species were taken in 554 hauls.

b. The five most common species were the bay anchovy, Atlantic silverside, white perch, silver perch, and winter flounder.

c. The greatest number of species and specimens per collection was taken in the summer followed by the fall, spring, and winter.

d. Seasonal trends for each major sampling area were generally similar to overall trends.

e. The greatest number of specimens per collection was taken in the waterways behind Brigantine; progressively fewer were taken in the Mullica River, Little Egg Harbor, and Great Bay.

f. In a comparison of habitats within bays from the inner bay out to the inlets, the number of fishes per collection decreased, but the species diversity generally increased.

g. Big and Little Sheepshead creeks were sampled in the fall and collections there resembled those of the mid and inner bays.

10. During 1972, an average of 4.445 eggs/m^3 and 0.085 larval and juvenile fishes/m^3 were collected in 189 surface, midwater, and bottom tows of 0.5- and 1-m plankton nets in the vicinity of the Site.

a. In the ocean, eggs of the bay anchovy (10.13%), tautog (1.95%), searobins (1.86%) and windowpane flounder (1.20%) comprised the major portion of identified eggs. Most eggs were collected from May through July.

b. From April through July larval and juvenile fishes were most abundant in the ocean. Larvae of the Atlantic menhaden, anchovies, fourbeard rockling, lined seahorse, northern pipefish, weakfish, American sand lance, and Atlantic mackerel were common.

c. A total of 229 surface collections with a 0.5-m plankton net in all bays and waterways yielded an average of 17.001 eggs/m^3 and 0.803 larval and juvenile fishes/m^3.

d. Monthly variations in the density of fish eggs were similar in each bay system in 1972. Peak density occurred in June. The majority of eggs collected was those of the bay anchovy.

e. The peak abundance of larval and juvenile fishes in the bay systems was in June (anchovies and silversides) and December (American sand lance). Anchovies, silversides, threespine stickleback, northern pipefish, American sand lance, and winter flounder accounted for 97.2% of the larvae taken in the bays.

f. The ichthyoplankton of the inlets was similar to that of the ocean and bays.

11. Sport fishing is a major year-round recreational activity in the area.

a. Data from charter boat and surf fishing creel censuses indicated that most fish were taken during July and August.

b. The dominant sport fishes in the vicinity of the Site included Atlantic mackerel, striped bass, weakfish, bluefish, and summer flounder.

12. Commercial fishermen working in the vicinity of the Site used otter trawls, pots, gill nets, and to a lesser degree, purse seines, fyke nets, and long lines.

a. The otter trawl fishery is basically for food fish such as scup, weakfish, and flounders. Fishing occurs year-round and it usually is offshore in winter and inshore in summer.

b. Pot fishing takes place from April through September. Black sea bass and American lobster are the primary commercial species.

c. Gill netting occurs from April through September. Bluefish and weakfish were the two most common fishes taken.

d. The following species may occur with varying frequency and abundance in the vicinity of the Site and are important both as sport and commercial fishes: weakfish, bluefish, striped bass, summer flounder, winter flounder, scup, black sea bass, silver hake, tautog, northern puffer, butterfish, yellowtail flounder, Atlantic mackerel, American shad, and Atlantic menhaden.

e. Commercial shellfish populations occur in both the ocean and bays along the New Jersey coast. The hard clam, oyster, and blue crab are important in the bays.

f. The surf clam is the most important shellfish landed in the state. Although it is usually taken more than 3 miles from shore, it is occasionally harvested in the vicinity of the Site.

13. Benthic invertebrates were collected with a ponar bottom grab, clam dredge, 25-ft semiballoon trawl, beach sieve, and lobster pot. More than 102,247 specimens representing 223 taxa were found in 399 collections taken in 1972.

a. The five most common species taken with the clam dredge in the ocean were the Atlantic surf clam, sand dollar, northern moon snail, common rock crab, and Atlantic moon snail. The five most common species taken with the trawl in the ocean were the snapping shrimp, sand dollar, Atlantic long-finned squid, common rock crab, and New England nassa.

b. Collections on the Ridge and at the Site were dominated by small bivalves. The average density for all organisms taken by ponar was 236 organisms/m^2 on the Ridge and 636/m^2 at the Site.

c. The bottom just landward of the Site was dominated by capitellid and ampharetid polychaetes; the average density for all organisms in ponar collections was 1,144/m^2.

d. The five most common species in clam dredge collections from Little Egg Inlet were the blue mussel, Atlantic surf clam, common rock crab, Atlantic slipper shell, and lady crab.

e. Ponar collections in shallow sandy areas of Little Egg Inlet were dominated by bivalves; the average density for all organisms was 995/m^2.

f. The hard clam, maldanid polychaetes, and the Atlantic jackknife clam dominated in clam dredge collections from Great Bay; the blue mussel, hard clam, and serpulid polychaetes dominated in Little Egg Harbor.

g. In most ponar samples from Great Bay, ampeliscid amphipods dominated; the average density of all organisms was 3,884/m^2.

h. Ocean beaches were dominated by spionid polychaetes, haustoriid amphipods, and the mole crab. Bay beaches supported diverse communities of polychaetes, bivalves, and crustaceans.

14. Marine algae were collected qualitatively by seine, trawl, and by hand.

a. Some of the more abundant species are discussed.

b. The most common forms were Ulva (sea lettuce), Agardhiella, Gracilaria, and Fucus.

15. Sampling for phytoplankton, protozoa, and inorganic nutrients commenced in May, 1972 both in the vicinity of the Site and in the bays.

a. Nutrients analyzed from May to July included reactive nitrite and nitrate, ammonia, and reactive silicate and phosphorus.

b. An inventory of phytoplankton and protozoa occurring in the vicinity of the Site from August through December, 1972 was based on an examination of small, live sample aliquots.

c. The enumeration of preserved samples collected at the Site in August showed a relatively high species diversity of phytoplankton and protozoa. Small species (less than 6 microns) such as naked flagellates and forms tentatively identified as blue-green algae dominated. Next in importance were diatoms, particularly Rhizosolenia spp., and small pennate species.

16. From January to June zooplankton was collected in conjunction with the ichthyoplankton study. Use of the Clarke-Bumpus sampler began in July.

a. At least 18 of the 23 common benthic invertebrates found in the vicinity of the Site are planktonic (meroplankton) during some part of their life cycle.

b. Larvae of blue mussel, Mytilus edulus, accounted for over 90% of the meroplankton during the fall.

c. The larvae of the rock crab, Cancer irroratus, and that of the American lobster, Homarus americanus, showed maximum densities in June and July.

d. Copepods comprised the major constituent of the zooplankton taken in surface samples. Species of Oithona were the dominant copepods.

e. Although total zooplankton/m^3 showed an increase with distance from shore during the fall, a significant difference between stations (P=.05) was not detected.

f. Zooplankton density during the fall averaged 18,731/m^3 in the ocean and 6,401/m^3 in the bays in surface samples taken with a #20 net.

g. Mysids and arrow-worms comprised most of the macroplankton during the fall, with greatest concentrations occurring near the bottom.

17. The terrestrial study began in June, 1972.

a. The study includes areas in a relatively natural state such as the Pine Barrens, salt marsh, and barrier beaches, as well as disturbed areas. The dominant vegetation in each area is described.

b. A list of the major plant species along Great Bay Boulevard, their areas of occurrence and relative abundance are presented.

c. Eight amphibian and 12 reptile species were collected.

d. The seasonal occurrence and relative abundance of 275 local bird species are presented.

e. A roadside census of local bird species began in September, 1972. Peak abundance of fall migrants occurred between 29 September and 20 October 1972 when 102 species were counted.

f. Data from the Brigantine National Wildlife Refuge were provided on waterfowl, marsh birds, shorebirds, and raptors which utilize the refuge. Endangered raptors observed in the refuge in 1972 included the bald eagle, golden eagle, osprey, and peregrine falcon.

g. The results of the annual New Jersey Aerial Waterfowl Inventory are presented. Population size, 1972 winter status, and food habits of 18 waterfowl species are included.

h. Birds commonly observed in the vicinity of the Site such as gulls, terns, and loons are discussed as are additional species which migrate over the ocean in the vicinity of the Site.

i. Information on mammals in the area was obtained from trapping, roadkills, and sightings. A total of 136 small mammals of 10 species were trapped.

j. Marine mammals sited in the vicinity of the Site included the harbor seal, Atlantic bottlenose dolphin, and Atlantic harbor porpoise.

k. Information is presented on the vegetation and animals in the vicinity of Great Bay Boulevard.

PHYSICOCHEMICAL DESCRIPTION OF THE PLANT SITE AND ADJACENT AREAS

PHYSICOCHEMICAL DATA

David L. Thomas

The physiography, sediments, water temperature, salinity, dissolved oxygen, pH, carbon dioxide, tides, and currents of the area were discussed by Thomas et al. (1972).

With each biological collection, water temperature, dissolved oxygen, and salinity were measured at the surface and, when possible, at the bottom. Water visibility was measured with an 8-inch diameter secchi disc. Air and water temperature (nearest 0.5 C) and dissolved oxygen (ppm) were determined using a Yellow Springs Instrument, Model 54, oxygen analyzer. Temperatures were checked using a mercury field thermometer. Salinity (ppt) was measured with an American Optical refractometer. Beginning in July, a Yellow Springs Instrument, Model 33, S-C-T meter was used to take salinity-temperature profiles at the Site. Other parameters measured for each collection are shown on the field sheets (Figs. 4 and 5).

Physicochemical data are summarized by month for collections taken in the vicinity of the Site during 1972 (Table 1). Water temperatures were lowest in February and March (2.5 C; 36.5 F), and increased about 5 C a month through July. Temperatures in August and September decreased only slightly from a high in late July. A sharp drop in temperatures occurred in October (mean for September was 19.2 C; that for October was 12.9 C).

Surface and bottom water temperatures at the Site were similar in May. During June, July, and August bottom temperatures averaged about 4 C lower than that at the surface. Occasionally differences of up to 7 C (12.6 F) between surface and bottom temperatures were noted at depths of 35 to 40 ft of water. During the fall, bottom temperatures averaged about 0.5 C higher than surface temperatures.

Mean surface salinities at the Site generally ranged between 29 and 31 ppt. Bottom salinities were usually somewhat higher than those at the surface.

Dissolved oxygen at the Site was highest in winter and lowest during the summer. Bottom values were lower than those at the surface. Lowest dissolved oxygen readings were in August when values averaged 7.6 ppm at the surface and 5.2 ppm at the bottom.

Surface temperatures were compared for the Site, Great Bay, and the Mullica River (Table 2, Fig. 6). Temperatures were lower in the Bay and River than in the ocan during the winter whereas during the summer they were much higher. In the last two weeks of July water temperatures averaged 29.7 C (85.5 F) in the River, 28.7 C (83.7 F) in the Bay, and 22.6 C (72.7 F) in the ocean. Differences between Bay and ocean temperatures were greatest in spring and early summer, and least during late summer and fall. During the fall, ocean temperatures were generally warmer than those in the Bay.

Temperature trends were generally similar within the three bay systems (Figs. 7-9). Temperatures were highest during the spring and summer months in the inner bay (back bay areas) and lowest at the inlet. During the fall, inlet temperatures were slightly higher than bay temperatures.

These temperatures were taken during trawl trips to the bays. Because time of sampling varied between bays, differences in water temperatures between bays are not directly comparable.

For the Great Bay-Mullica River system Durand and Nadeau (1972) found that the lowest water temperatures occurred in early February (-1.5 C, 29.3 F) and the highest were in July (27-28 C, 80.6-82.4 F). They reported that the River and parts of the Bay froze periodically from late December to early February and that occasionally the entire Bay was frozen. The winters of 1971-1972 and 1972-1973 were relatively mild and there were only brief periods when the Mullica River and Great Bay had ice.

Salinities were compared for the Site, Great Bay, and the Mullica River (Table 3, Fig. 10). They varied the most in the River, and the least at the Site. In the Mullica River the lowest salinities were recorded in winter, and the highest were measured in late summer and fall. Salinity dropped in all three areas during late June due to fresh water runoff following tropical storm Agnes. A significant drop in salinities at the Site was noted from 19 to 20 June 1972. On 19 June, salinity averaged 29.9 ppt at the surface and 31.5 ppt on the bottom; on 20 June surface salinity dropped to 25.7 ppt and that at the bottom to 30.6 ppt. Durand and Nadeau (1972) reported that after a brief period of heavy rain in 1969 the salinity at Turtle Island which is located near the mouth of the Mullica River, dropped from 17 to 4 ppt in 3 days.

Temperatures may also show relatively large variations over a short time period. During summer, colder bottom waters from the ocean occasionally moved into beaches such as at Holgate, Long Beach Island. On 29 August 1972 surface ocean water temperatures were about 19 C. Surface temperature at Sea Horse Pier on Brigantine was 19.5 C, while that at Brigantine Inlet was

18 C. Water temperature at Holgate dropped to 15.5 C in the afternoon and was 14.5 C by evening. Bay water temperatures on the opposite side of the Island were 19 C during the day and 18.5 at night. Further evidence of cold ocean water at Holgate was the presence of several individuals of a boreal pelagic pteropod which were taken by seine.

Large differences between bay and surf temperatures like those above were often noted. On 22 May the water temperature at Paxon's Motel (Station 17) in Absecon Bay was 18.3 C while in Absecon Inlet it was 14.4 C. On 5 June the temperature at Paxon's was 23.5 C, in Absecon Inlet it was 20.5 C, and in the surf at Brigantine it was 14.5 C.

Extremes in physicochemical parameters are often important in limiting the distribution of organisms. In the vicinity of the Site during 1972, surface temperatures ranged from 0 to 26 C (32-78.8 F); surface salinities were from 23.3 to 32 ppt. In the Great Bay-Mullica River estuary surface temperatures ranged from 0 to 31 C (32-87.8 F) and surface salinities were from 0 to 30 ppt.

Utilization of the Mullica River by many species is probably limited because of its acid waters. Values of pH ranged from 6.0 to 7.0 at the mouth of the Mullica River to 3.5-4.5 near the upper limit of tidal waters at Batsto.

The tidepool is another habitat where organisms are exposed to extremes in physicochemical parameters. Summer temperatures reached 36 C (96.8 F) in the tidepools near Great Bay Marina. Salinities there varied between 10.5 and 30 ppt while dissolved oxygen recorded during the day ranged from 3.8 to 13.8 ppm. One tidepool along Great Bay Boulevard had a salinity of 59.9 ppt on 29 August 1972.

Air temperatures for each daylight trip to the Site are presented in Table 4. The lowest air temperature was -3.5 C (26 F) on 23 February 1972; the highest was 30 C (86 F) on 24 July 1972.

Weekly air temperatures recorded with a maximum-minimum thermometer located in an oak-pine woods at Absecon are shown for 24 July 1972 through 1 January 1973 (Table 5). The highest temperature (33.9 C, 93 F) and highest mean temperature (24.7 C, 76.6 F) for this period was during the week of 24 to 30 July. The lowest temperature (-11.1 C, 12 F) occurred in the period from 12 to 18 December. The lowest mean temperature (3.2 C, 37.6 F) was during the period of 20-28 of November.

SEDIMENT

Jeffery J. Hondo

Surface sediments were examined to determine bottom types and animal-sediment relationships. Young et al. (1971) demonstrated a high correlation between community structure and percentage of clay and silt in the sediment. Durand and Nadeau (1972) in a study of the Great Bay-Mullica River estuary, correlated the distribution of benthic species and sediment type.

Sediment samples were taken at every station sampled by Ponar bottom grab by making an extra drop of the grab and taking a 500-cc subsample from it. Beach sediment samples were taken by scraping the top 2 cm of material at the water line into a 500-cc jar.

All sediment samples were washed three times in fresh water to remove salt. Organics were oxidized using 30% hydrogen peroxide and the sediments were then dried in an oven at low temperature.

More than 200 samples were taken from the bays, inlets, and beaches in the Great Bay-Little Egg Inlet area. Approximately one-fourth of these have been analyzed. Ninety-five samples, 77 of which have been analyzed were collected in an area of approximately 9 square miles around the Site from February to December, 1972.

Two methods were used to determine grain size. A settling tube made available by the State of New Jersey Bureau of Geology and Topography was used to analyze 60 of the ocean samples. The remaining samples were done by standard sieve analysis (Folk, 1968). A comparison of the two methods showed similar results in determining grain size percentages.

Settling tube analysis consisted of dropping a randomly split subsample (8-10 gm) into a water column of known height. A percent frequency curve was plotted on a chart recorder as particles accumulated at the bottom of the tube.

In sieve analysis a randomly split subsample of 40 gm was passed through a set of graduated sized sieves. The amount of sediment retained on each sieve was weighed and these values were used to draw a percent frequency curve. Statistical parameters such as the mode and mean were then obtained by graphical inspection. The numerical data were translated into the Wentworth size classification (Table 6) in order to group samples and map general sediment distribution.

A Ridge, the axis of which runs in a general northeast-southwest direction, lies at the seaward margin of the Site. Sand ridges are fairly common features along the Middle Atlantic continental shelf south of New York (Swift et al., 1972). These ridges appear to be maintained by the general southwest drift system along the Middle Atlantic coast of the United States. A description of the bathymetry and oceanography of the study area is given by Thomas et al. (1972).

From the barrier island-sandbar complex separating Little Egg and Beach Haven inlets to the Ridge near the Site, the shelf has a slope of about 20 ft per mile. A shallow trough is outlined by the 40-ft contour on the landward side of the Ridge. The maximum depth of the trough to the north of the Ridge is 46 ft. The Ridge is 2,000 ft wide and 7,200 ft long and its crest lies at a depth of 25 ft, mean low water.

The sediment distribution in the vicinity of the Site follows the bathymetric contours and can be divided at the Ridge into two major divisions (Fig. 11). The sediments on the seaward side of the Ridge are characteristically medium-to-coarse-grained, moderately well sorted quartz sand. On its southwest and northeast sections, the Ridge is composed of medium, well sorted quartz sand. Coarse sand separates the two regions. Storm wave action is evident across the much shallower Ridge axis as seen by a turbid zone outlining the Ridge during storm conditions. A region of fine sand and silt (Fig. 11) extends into Little Egg Inlet. The very fine-grained sand is highly mobile. Depending on storm conditions, this sand is alternately scoured and deposited in the zone between the inlet sandbars and the Ridge. Samples from the same area showed smaller percentages of very fine sand after storms, particularly northeasters, than during other periods. The area of fine-to-very fine-grained sand (Fig. 11) represents an average based on samples taken over 11 months. The actual distribution of the very fine sand at a given time may vary. It may extend to the southwest edge of the Ridge during long periods of calm weather, or it may be absent after a major storm or a long period of rough seas. The sand and silt in this zone can be characterized as the nearshore, modern sediment facies.

The sediments of Beach Haven, Little Egg, and Brigantine inlets are basically medium-to coarse-grained, moderately sorted quartz sand with some shell hash and heavy minerals. The main channels at Shooting Thorofare and Brigantine Inlet have maximum depths of 40 ft and have strong tidal currents. Velocities of tidal currents are listed in Thomas et al. (1972). Currents of high velocity scour all but the coarsest sands. The bottom around Little Egg Inlet Buoy "F" is composed of high percentages of whole and broken clam and oyster shell hash. Tucker's Island sandbar is composed of medium-to fine-grained, well sorted quartz sand.

The sediment distribution in Great Bay, from the inlets to Shooting Thorofare and Grassy Channel, grades from coarse to medium-grained, moderately sorted quartz sand (Fig. 12). Deposits of very fine sand, silt, and clay along with gravel are found along the shore line of Shooting Thorofare. This poorly sorted sediment is derived from a combination of various sources in the marsh and Little Egg Inlet. Grain size decreases to fine sand at the Seven Island sandbar complex and to very fine grained sand and silt in the intracoastal waterway. Bottom sediment in lower Great Bay is basically very fine sand and silt with some oyster shell hash. Main Marsh Thorofare is mostly composed of silt. The beaches of Great Bay are composed of coarse sand and gravel which are probably artificial fill, overlying marsh deposits.

FISH

David L. Thomas

Materials and Methods

Fish were collected from Little Egg Harbor, Great Bay, and the Mullica River; the waterways behind Brigantine; Absecon, Brigantine, Little Egg, and Beach Haven inlets; and in the ocean from the surf to 6 miles from shore in the vicinity of the Site. Collections were also made in tidepools, in two freshwater spillpools, and in freshwater tidal portions of the Mullica River.

The gear usually employed to collect fishes included the trawl and seine. To collect demersal fishes, a 25-ft trawl was used in the ocean and a 16-ft trawl was employed in the bays. The seine was used to collect larval, juvenile, and adult forms of marine and estuarine species which frequented the shore zone. Plankton nets were employed to sample fish eggs and larvae. Occasionally small juvenile and adult fishes were also taken with this gear. Gill nets were used to capture pelagic and semi-demersal fishes. These fishes comprised a large portion of the fish community in the vicinity of the Site during the spring, summer, and fall, and gill nets will be used more extensively in future studies. Information on many of the larger fishes in the area was obtained from sport and commercial fisheries data. Several lobster pots were used to collect fishes and macroinvertebrates typically found around artificial structures.

Many fishes were preserved in the field in 10% formaldehyde. If a large number of individuals of a species was collected, a subsample was preserved and the remainder was counted and released. A field sheet was completed for each collection (Fig. 4).

After one week in formalin, the fish were washed and stored in 40% isopropyl alcohol. All collections were sorted to species. Individuals of each species were counted and measured to the nearest mm. For a large sample of a species, 50 individuals were taken at random and measured. Lengths of most fishes were taken from the tip of the snout to the distal portion of the central rays in the caudal fin (fork length). Total lengths were taken on fishes such as sharks and rays or on fishes with a convex caudal fin (eg. winter flounder).

The following statistical tests were used for seine and trawl data analyses. An index of affinity (Fager, 1957) was first used to determine which fishes were associated. A one-tailed t-test was employed using the formula, $t = \left[\frac{(NA + NB)\ (2J - 1)}{2NANB} - 1\right]\sqrt{NA + NB - 1} \geqq 1.645$. NA was the number of occurrences of species A, NB the number of occurrences of species B, and J the number of joint occurrences. Affinities between pairs of species determined recurrent groups. Recurrent groups represented species collected together with greater frequency than expected by chance. Those species which occurred with at least one member of a recurrent group more often than was expected by chance were considered associates.

Species diversity is a measure of the variety of species and their abundance in an area. The Shannon-Weaver Diversity Index (Information Theory), as discussed in McIntosh (1967) and Pielou (1966a, b), was used to evaluate species diversity. The equation employed was $D = -\sum_{i=1}^{s} \frac{ni}{N} \log_e \frac{ni}{N}$ where ni was the number of specimens of species i and N the total number of specimens.

The Distance Measure, as discussed in McIntosh (1967), was used to measure the similarity between two communities. Communities which have few species in common will have a Distance value close to one, whereas those which are composed of similar species in the same relative abundance will have a distance value close to zero. The "distance" between two sampling areas in our study was determined by the formula, $Djh = \sqrt{\sum_{i=1}^{s}\left(\frac{nij}{Nj} - \frac{nih}{Nh}\right)^2}$, where nij was the number of specimens of species i taken in area j, nih the number taken in area h, Nj the total number of specimens taken in area j, and Nh the total number taken in area h. Relative abundance (ni/N) was used here to avoid masking differences due to unequal sampling effort.

Discussion

A total of 123 species of fish representing 57 families was collected in 1972 (Table 7). These species are listed alphabetically by scientific (Table 8) and common name (Table 9). In general, common names are used in the text for ease in discussion whereas scientific names are given in the tables for consistency with other scientific literature. An additional 40 species previously reported from the study area and adjacent waters by a number of workers (Bean, 1888; New Jersey Department Environmental Protection 1972a, 1972b; McDermott, 1971; and Marcellus, 1972) but which have not been taken to date in this study are listed in Table 10.

Fishes collected in 1972 were classified by their temporal distribution within the study area (Table 11). These categories and the number of species in each, included the following: year-round residents (40), including fresh water (14) and salt water (26); winter (7); spring-fall-winter (7); summer (27); and summer-spring-fall (28). Each category represents the time of year when most of the included species occurred. The largest category was the summer-spring-fall species. These fishes entered the area in spring, were most common during summer, and left during the fall. Summer species comprised the second largest category. These fishes were here generally only during the warmer summer months and included a number of subtropical and tropical strays such as the spotted goatfish and orange filefish.

A total of more than 326,000 juvenile and adult fishes was collected by seine, trawl, gill net, and lobster pot during 1972 (Table 12). This total included the following number of specimens and species by season: winter, 10,400+ specimens (44 species); spring, 33,100+ (76); summer, 211,300+ (93); and fall, 69,700+ (76). An equal number of species was collected during the spring and fall. The large number of specimens taken in fall was due mostly to the large number of young (0+ year class) of the bay anchovy and Atlantic silverside.

Fifty-one species were each represented by 100 or more specimens in 1972. These are discussed briefly below in order of their numerical abundance. Salinities at which each species was collected by season are presented in Tables 13 to 16. Length-frequency data are given for some of the more important fishes (Tables 17 to 24). Further information about each of these fishes is included in the sections which follow.

1. The Atlantic silverside (160,600+ specimens) comprised 49% of all fish specimens collected in 1972. Of these, 98% were taken in the shore zone by seine; most (77%) were collected during the summer. This was the most abundant and widely distributed species in the shore zone. Spawning occurred in the bays from mid-May to June.

2. The bay anchovy (79,700+ specimens) was the second most abundant species and comprised 24% of all specimens taken. Most were taken by trawl either in the ocean (45%) or bays (45%). Sixty-seven percent were taken in

the summer and 21% were captured in the fall. This species dominated in ocean trawl collections in depths from 5 to 39 ft during September and October. This is an important forage fish for many sport and commercial fishes. Spawning occurred primarily in the bays in June.

3. The striped killifish (14,900+ specimens) comprised 5% of all specimens taken. Almost all were collected by seine. It occurred throughout the year although most were taken in the summer (45%) and fall (45%). It spawned during the spring in the bays and along ocean beaches.

4. The mummichog (12,800+ specimens) comprised 4% of all specimens taken. Most were taken by seine. It occurred throughout the study area at almost all salinities. It is a year-round resident although it was taken mostly in the summer (50%). Spawning occurred during the spring.

5. The banded killifish (5,800+ specimens) is a year-round resident, particularly in brackish and fresh water areas. A few were taken at salinities above 20 ppt. All were taken by seine; most were from the Mullica River and a few were from freshwater spillpools. It spawned during the spring.

6. The sheepshead minnow (5,200+ specimens) was collected exclusively by seine. It was generally restricted to tidepools or protected areas and usually in association with vegetation. Spawning occurred during spring in the bays.

7. The red hake (4,226 specimens) was the most numerous commercial species taken. It was second numerically of all fishes collected in the vicinity of the Site and was the dominant demersal fish there in fall, winter, and spring. Length-frequency distributions are presented in Table 17. Adults and sub-adults were collected at the Site in May and June, and in November and December. Most individuals collected were young (0+) or juveniles. Almost all were taken in the ocean by trawl (99.9%). Most specimens were

captured during the fall (63%) and spring (24%). It usually occurred at salinities of 27-32 ppt. The red hake spawns in the ocean mostly during April and May. Only a few larvae were collected in the study area.

8. The tidewater silverside (3,790+ specimens) was collected almost exclusively by seine. Most individuals were taken in fall (63%). This fish was generally collected in low salinity water in the summer and at higher salinities in winter (Tables 13 and 15). It occurred in tidepools at salinities up to 59 ppt. It generally spawns in May and June.

9. The spot (3,380+ specimens) occurred in the area predominately during summer (91%). Most specimens were taken by seine (86%). One collection made with a 250-ft beach seine on 9 August 1972 took over 2,600 specimens. All individuals collected in 1972 were apparently young (0+ year class). The spot spawns in the ocean during winter and spring. However, no eggs or larvae were collected in this study.

10. The silver perch (2,990 specimens) was common in the bays during summer. About 54% were taken by seine and 32% by trawl in the bays. Most were collected in summer (78%) and fall (21%). Spawning occurred primarily in June and July although no eggs or larvae were collected. Young (0+) collected in October ranged in size from 45 to 120 mm FL (Table 18).

11. The white perch (2,767 specimens) is the most abundant estuarine sport fish in the area. The lower Mullica River was the most important area for this species. It was taken throughout the year in the bays and was collected predominately by trawl (78%). The white perch spawned locally in fresh and low salinity water during the spring.

12. The fourspine stickleback (2,539 specimens) was taken mostly in winter (37%) and spring (44%). About 92% were taken by seine. This species spawned locally during the spring.

13. The winter flounder (2,444 specimens) occurred in the study area throughout the year; spring (40%), summer (38%), fall (11%), and winter (10%). It was taken by seine (48%), trawl in the bays (33%), and trawl in the ocean (19%). The length-frequency distributions of 2,256 winter flounder collected in 1972 exemplify the movement of this species between the bays and ocean (Table 19). During January and February the winter flounder was taken in the ocean and bays. It moved into the bays in large numbers during March and April. Adults moved offshore in May and June and were generally absent from the study area during summer. Young (0+) appeared in the shore zone and shallow areas of the bays in June and were common throughout the summer and fall. By December most young ranged in length from 85 to 165 mm FL. Adults were most abundant in the vicinity of the Site in May and June. Spawning occurred in the bays and ocean from February to April.

14. The Atlantic menhaden (2,394 specimens) occurred during all seasons. Most were collected during spring (24%), summer (38%), and fall (27%). Although it ranked only 14th it was one of the most numerous species during the summer and early fall at which time large schools frequently passed the Site. June (1972) estimated the average number of menhaden within a school in the Atlantic to be about 87,000 fish. This pelagic species generally avoided the sampling gear used. Most specimens collected were young taken in the shore zone by seine (81%). Ninety-nine young taken by trawl near the Site in February averaged 85 mm FL. Spawning occurred primarily during May and September.

15. The silver hake (1,800 specimens) occurred predominately in trawl collections in the ocean during the fall (59%) and spring (38%). During these seasons it was a major component of the demersal fish community. Most individuals collected were young (0+ year class) or juveniles. Length-frequency distribution

of 1,214 silver hake are presented in Table 20. It occurred at salinities of 27-31 ppt. Spawning apparently takes place offshore from June through August.

16. The windowpane flounder (1,566 specimens) occurred throughout the year although it was most common in the spring (48%). About 70% were taken in the ocean by trawl. Occasionally this was one of the most numerous species in the vicinity of the Site. It ranked first by frequency of occurrence in trawl collections in the ocean. It spawns in the ocean primarily in the spring and fall (October).

17. The American sand lance (1,500+ specimens) occurred in the area throughout the year although it was most numerous in summer collections (70%). Some 76% were taken in the ocean by trawl. This species burrows into the substrate and was usually not susceptible to collection. On 28 July 1972, over 1,000 specimens were taken by trawl on the Ridge at the seaward margin of the Site. It spawns in the vicinity of the Site from November to February.

18. The northern pipefish (1,356 specimens) occurred throughout the year: 8% were taken in winter, 28% in spring, 34% in summer, and 28% in fall. Some 43% were taken by seine; 39% were taken by trawl in the ocean. Young specimens were common during June and July.

19. The spotted hake (1,322 specimens) occurred throughout the year but most were taken in spring (72%). Most were taken in the ocean by trawl (87%). It was generally collected at salinities of 25-32 ppt; a few were taken at 17-20 ppt. It and the white hake were the only hakes taken commonly during summer. The spotted hake spawns offshore primarily during October and November. Length-frequency distributions of 924 spotted hake taken in 1972 are presented in Table 21.

20. The weakfish (1,293 specimens) occurred most commonly during the summer (83%). Most were taken in the ocean by trawl (86%). The majority

of these were young; adults tended to avoid the trawl. The weakfish was the most common species caught by sport fishermen in the study area in 1972 and large schools of adults were often observed in the vicinity of the Site during summer and early fall. It spawns from late spring through the summer. Most larvae in 1972 were taken in mid-July. Young (0+) collected in October ranged in size from 60 to 210 mm FL (Table 22).

21. The alewife (1,258 specimens) occurred throughout the year. Most specimens collected were young (0+). The adults enter tidal freshwater in spring to spawn. Young were common during winter near the Site. On 10 March 1972, 119 yearlings collected near the Site averaged 80 mm FL.

22. The bluefish (958 specimens) was common during summer (92%). Most of those collected were young; 96% were taken by seine. Schools of adults were often common near the Site but generally avoided the trawl. Adults spawn locally about 20-50 miles offshore in June and July (Clarke, 1972).

23. The blueback herring (862 specimens) occurred during the fall (36%), winter (37%), and spring (26%). Most specimens collected in fall were taken in the bays; most taken in the winter were from the ocean. Almost all specimens collected were young (0+). One hundred young collected near the Site on 10 March 1972 averaged 73 mm FL. Adults enter tidal fresh water creeks to spawn. However, no spawning adults were collected in 1972.

24. The butterfish (852 specimens) was most common during the summer (42%) and fall (50%). Most (91%) were taken by trawl in the vicinity of the Site. Of all fishes taken by trawl in the ocean, it ranked eighth numerically. Many larvae and juveniles were taken in plankton tows in the ocean during August and September.

25. The American eel (791 specimens) occurred throughout the year. About 90% were taken by seine. Most were taken during the winter (28%) and

spring (46%). Elvers entered the area during winter and early spring. Many adults overwintered in the mud and sand of tidal ditches. Only three specimens were taken in the ocean.

26. The white mullet (762 specimens) was taken exclusively by seine. Most individuals collected were small young. This species was most common in the summer (76%), and less common in spring (12%) and fall (12%).

27. The striped anchovy (703 specimens) occurred most commonly in the summer (87%). Most (67%) were taken by seine; some (27%) were captured by trawl in the ocean. Large adults were collected with a 250-ft beach seine during late spring. Spawning occurred during July in the ocean.

28. The northern searobin (665 specimens) was the more common of the two searobins collected. Most were taken during spring (54%) and summer (42%). Some 92% were taken in the ocean by trawl while only 6% were taken in the bay by trawl. Spawning apparently occurs during the summer offshore of the Site although some 6,000 eggs were taken in the vicinity of the Site.

29. The white hake (568 specimens) was collected predominately during spring (63%) and summer (34%). Most were taken in the ocean by trawl (93%). Most individuals collected were young (0+); a few larger specimens were taken in November and December (Table 23). Most were collected at salinities of 25-31 ppt but a few were taken at 12-18 ppt.

30. The smooth dogfish (553 specimens) was taken predominately during the summer (47%) and spring (35%). Most were taken by trawl; 69% were collected in the ocean and 16% in the bay. This was occasionally one of the dominant demersal species in the vicinity of the Site during the summer.

31. The pollock (451 specimens) was most abundant during spring (94%). All specimens collected were young (0+). They arrived during winter and left the area by late spring. Most (82%) were collected by seine in the bays.

32. The smallmouth flounder (438 specimens) occurred throughout the study area and was a year-round resident. It was taken predominately in the spring (51%), fall (23%), and summer (20%). Most individuals were collected by trawl in the ocean (67%); fewer were collected by trawl (15%) and seine (5%) in the bays.

33. The golden shiner (419 specimens) was taken exclusively by seine. Most specimens were collected during spring (52%) and summer (29%). It occurred in fresh or low salinity tidal waters up to 12 ppt.

34. The striped searobin (311 specimens) was collected in the area during the summer (75%), spring (13%), and fall (11%). Some 83% were taken in the ocean by trawl. Only 8% were taken in the bays by trawl and 7% by seine. Most were taken at salinities of 26-32 ppt.

35. The hogchoker (293 specimens) was collected throughout the year. Most individuals were taken in the bays by trawl (83%), especially during spring (54%) and summer (39%). This is a euryhaline species and was collected at salinities from 0 to 30 ppt.

36. The scup (280 specimens) was most common during summer (64%) and spring (22%). It was about equally distributed in trawl catches from the ocean (50%) and bays (45%). Most were taken at salinities above 23 ppt.

37. The rainwater killifish (276 specimens) was taken exclusively by seine, primarily during summer (89%). Most specimens were taken in tidepools.

38. The pumpkinseed (271 specimens) was taken exclusively by seine, primarily during summer (45%), spring (40%), and fall (15%). All of the 271 specimens were taken in fresh or brackish water up to 5 ppt.

39. The northern kingfish (231 specimens) was collected predominately during the summer (83%). Some 55% were taken by seine; 42% were collected by trawl in the ocean. Most were collected at salinities above 25 ppt.

40. The American shad (216 specimens) was collected primarily in the ocean by trawl (78%). Most individuals were taken in winter (58%) and spring (29%). Those specimens collected by trawl were young (0+) over-wintering in the vicinity of the Site. One hundred and eight individuals collected in the ocean in March averaged 106 mm FL. Some adults were taken by gill net in Great Bay during April. Nichols (1958) found that 81% of the returns of adults tagged from pound-nets set off Beach Haven, New Jersey, in the spring were from the Hudson River.

41. The striped mullet (193 specimens) was collected exclusively by seine. Most specimens collected were juveniles or adults taken during the fall (81%) on their southward migration.

42. The lined seahorse (184 specimens) was collected predominately by trawl: 65% were taken in the ocean and 34% in the bays. Most specimens were taken in spring (75%). Most young were taken by plankton tows in the ocean during July and August.

43. The threespine stickleback (183 specimens) was taken most often by seine (78%): 20% were taken by trawl in the bays. It was common in winter (54%) and spring (44%). Most small young were collected from mid-May to early June. Some ripe adults were found in tidepools.

44. The little skate (169 specimens) was taken exclusively by trawl in the ocean. It was taken predominately in the spring (73%) and fall (22%). Most were taken at salinities of 28-32 ppt.

45. The oyster toadfish (148 specimens) was taken predominately in the bays: 62% by trawl, 36% by seine. Most specimens were taken in the summer (55%), fall (22%), and spring (21%).

46. The tautog (139 specimens) occurred throughout the study area. Many of those taken in the ocean were from lobster pots located at the Site.

It occurred predominately in summer (45%) and fall (35%) collections. It is common about wrecks, jetties, and pilings. The tautog may be considerably more numerous than indicated by trawl catches because of the difficulties of sampling its preferred habitats.

47. The northern puffer (125 specimens) was taken predominately by trawl in the ocean (72%) and bays (19%). Half of the specimens were taken in the summer. The puffer population has been low in the study area for the past several years. Relatively few were taken by sport fishermen in 1972 whereas it made up 66% of the boat sport fishing catch in Great Bay during 1969 (Hamer, 1972).

48. The naked goby (115 specimens) was taken predominately in the bays: 78% by seine and 20% by trawl. Most were collected during the summer (76%) and fall (21%). A number were collected with benthic sampling gear in areas populated by oysters and hard clams.

49. The summer flounder (113 specimens) was taken in the bays (49% trawl; 20% seine) and ocean (28%). It was most common in summer (44%) but was also taken in the spring (36%) and fall (18%). The length-frequencies of 104 specimens are presented in Table 24. Only three specimens were apparently young (0+). Most specimens were taken at salinities over 20 ppt. Only nine larvae were collected in 1972; one in the ocean in November; seven in Absecon Inlet in February, March, and April; and one in Little Egg Harbor in March. This is an important sport and commercial species. Many are taken by sport fishermen in the bays and inshore ocean during summer. Our low trawl catches may be due to net avoidance.

50. The white catfish (105 specimens) was collected exclusively by trawl in the Mullica River. It occurred in samples throughout the year although most individuals were taken in spring (49%). It was taken at salinities of 10 ppt or less.

51. The striped cusk-eel (101 specimens) was taken predominately by seine (54%); 42% were collected by trawl in the ocean. Most specimens were taken in the spring (48%). They were more common in seine collections taken at night than those taken during the day. This is a burrowing form which often is not susceptible to collection by seine or trawl.

The four most common species comprised 82% of all specimens taken during 1972. They are all short-lived forage fishes which are widely distributed throughout the study area. Three of these four species were year-round residents; the bay anchovy was scarce during winter.

The numerical abundance of each species is reflected in part by the sampling gear. Larger fishes and semi-demersal and pelagic forms generally avoided collection. Thus numbers reported for species such as the Atlantic menhaden, bluefish, weakfish, and striped bass are very low and not indicative of their abundance in the area. Information on these species is gained primarily from the sport and commercial fishery as well as from records of fish schools sighted in the area. The greater use of gill nets in the future should provide additional data on the pelagic, semi-demersal, and larger demersal species able to avoid the trawl.

Each piece of gear generally samples a distinct portion of the community of fishes. Small seines collect small fishes of the shore zone and young of many larger marine and estuarine species. Trawls take demersal fishes but are often avoided by larger, fast swimming species. Gill nets sample semi-demersal and pelagic forms. The Distance Measure (as discussed by McIntosh, 1966) was applied to the seine and trawl data from Little Egg Harbor. A value of 0.95 was obtained indicating that there was little similarity in the composition of the communities sampled by seine and trawl. Thus a variety of gear have to be used to adequately describe the populations of fishes in an area.

The following sections will discuss the sampling schedule, materials and methods, and results for each major collecting method for fishes. Seasonal discussions are based on samples from winter (January-March), spring (April-June), summer (July-September), and fall (October-December).

SEINE COLLECTIONS

Richard C. Bieder and Eric A. Illjes

Introduction

The shore zone is an important breeding, nursery, and forage area for many fishes. The objectives of the seine program were to determine the distribution and abundance of species utilizing the shore zone; to compare differences in species composition between habitats day and night; and to examine the role of the shore zone in the ecology of local fishes.

Materials and Methods

Regular seine stations (Table 25; Figs. 1 and 2) were sampled once every two weeks when possible. One station in Great Bay, three stations in Little Egg Harbor, and three stations in Brigantine were sampled both day and night to determine the diel movements of fishes. Additional stations were sampled periodically (Table 26).

The two seines used at most stations were a 15-ft common seine and a 25-ft bag seine. The former is 15 x 4 ft with 1/8-inch stretch mesh; the latter is 25 x 4-ft with a 4 x 4-ft bag. A 75-ft bag seine was used occasionally. It is 75 x 6 ft with a 6 x 6-ft bag. Both 25 and 75-ft seines are constructed of 1/4-inch stretch mesh. A 250-ft beach seine was used at three locations on Brigantine Island. It is 250 x 10-ft with 1/2-inch stretch mesh and has a 10 x 10-ft bag.

The 15- and 25-ft seines were used at the regular stations. Standard seining procedure with the 25-ft bag seine included two or three hauls over approximately 100 yards of shoreline. Hauls were taken with the 15-ft seine at the station to collect larval and young fishes. Hauls were made until no additional species were collected. This insured the capture of most species present at the station.

The 75-ft bag seine was used to capture anadromous herrings (Alosa spp.) in the spring in Nacote Creek (Station 24) at the Port Republic spillpool. The seine was dropped from the roadway bridge and pulled to shore. The seine was also used at the old Coast Guard Station (Station 13) on Long Beach Island over a broad sand-mud flat.

The 250-ft beach seine was generally set in a semicircle from shore with a 14-ft boat. Between 100 and 400 ft of line was attached to each brail to increase the area sampled. The net was then pulled to shore by truck or by hand.

Results - Small Seines

Species composition and physicochemical parameters for each collection are given in Appendix Tables 1 to 12. The species composition and catch frequencies by season for each station are presented in Tables 27 to 55. Area totals are presented in Tables 56 to 61.

More than 208,688 specimens of at least 74 species were collected by use of the 15-ft, 25-ft, and 75-ft seines in 1972. The seasonal distribution of the catch was as follows: winter, 7,203 specimens of 25 species; spring, 17,216+ specimens of at least 47 species; summer, 144,174+ specimens of at least 62 species; and fall, 40,095+ specimens of 35 species (Table 62). The number of specimens per collection for each season was 88 for winter, 101 for spring, 644 for summer, and 246 for fall.

The five most common species taken by small seines were forage fishes. These were the Atlantic silverside (150,468+ specimens), striped killifish (14,539+), mummichog (12,576+), banded killifish (5,772+), and the sheepshead minnow (5,175+). In spring, the fourspine stickleback replaced the sheepshead minnow as the fifth most numerous species. The bay anchovy appeared in largest numbers (2,883+) in summer, and ranked fourth in place of the banded killifish. In fall, the tidewater silverside ranked fourth.

The Atlantic silverside was common throughout the year, and was abundant in summer due to recruitment of numerous small young. Single collections of 5,000+ individuals occurred at this time. This species composed 72.1% of all fishes taken by small seines in 1972.

Both the striped killifish and mummichog were common in brackish water. The striped killifish was restricted to higher salinity waters while the mummichog occurred at salinities ranging from 0 to 60 ppt. The mummichog appeared in greater numbers in spring and summer, while the striped killifish dominated in fall and winter. Although a few striped killifish were taken by bay trawl during the winter, there was little evidence of movement by either species into deeper water at this time. Both species may burrow in mud during very cold periods and are not susceptible to collection.

The banded killifish was taken in almost every sample at very low salinity and was occasionally collected in water with a salinity of 22.0 ppt. This was the dominant forage fish in the shore zone of freshwater areas.

The sheepshead minnow was abundant in tidepools and other areas with a mud bottom. The sheepshead minnow, mummichog, and striped killifish were found over a wider range of temperatures and salinities than the other forage species collected. Along with the Atlantic silverside, they made up 87.6% of the fishes collected by small seines.

The fourspine stickleback ranked fifth in numerical abundance in the spring. Breeding occurred in early spring when a large number of adults was taken in the shore zone. In summer, the number of adults decreased although juveniles occurred frequently.

During summer and fall the bay anchovy was abundant throughout the area and large numbers of larvae and young were collected in the shore zone.

In fall, the tidewater silverside showed a marked increase in abundance. This increase was in part due to their movement to higher salinity waters as temperatures decreased.

Two stations from each habitat were analyzed for species frequency of occurrence. Habitats selected were the tidepool (Stations 4 and 27, Table 63); protected sand beach (Stations 21 and 23, Table 64); mud-sand shore (Stations 2 and 16, Table 65); surf zone (Stations 14 and 18, Table 66); and low salinity, mud-sand shore (Stations 6 and 8, Table 67). Temperature and salinity data are presented for one station of each habitat type in Figs. 13 and 14.

Tidepool (Table 63)

The mummichog and sheepshead minnow were collected most frequently, occurring in 31 of 32 samples (F=97%). The striped killifish was second in frequency of occurrence (F=78%). These three species are euryhaline and eurythermal, a requirement for year-round residence in a tidepool system.

The tidewater silverside ranked third by frequency of occurrence. The species was most abundant during the fall. Spawning apparently occurred in low salinity waters during spring. The young moved into higher salinity water and tidepools later in the year.

The spotfin killifish ranked fourth, and in 1972 was collected only at Station 4, a tidepool near Great Bay Marina. It was collected in other tidepools sampled along Great Bay Boulevard during the winter of 1973.

The Atlantic silverside and rainwater killifish ranked fifth in frequency of occurrence in the tidepools. Neither occurred commonly until summer and fall, when they occurred in about 50% of the collections. All of the above species occurred as juveniles and adults in the tidepools.

Protected sand beach (Table 64)

The Atlantic silverside ranked first (F=81%), and was often collected in large numbers. The mummichog ranked second in frequency (42%) and the sheepshead minnow ranked third (36%). The striped killifish occurred in 34% of the samples while the windowpane flounder occurred in 21% of the collections. All of the above species were collected as juveniles and adults. Most windowpane flounder collected were young (0+) or juvenile.

Mud-sand shore (Table 65)

The Atlantic silverside was the most frequently collected species (95%) in this habitat. The striped killifish occurred in 89% of the collections and the mummichog in 64%. These species were taken as juveniles and adults. The northern pipefish appeared in 36% of the collections; most specimens taken were adults. Winter flounder (F=34%) were predominately young (0+ year class) and juveniles.

Samples from the above habitats showed little variation in the composition of the most frequently occurring species. Members of the families Atherinidae (silversides) and Cyprinodontidae (killifishes) predominated for the year. A spring increase in the number of species taken in mud-sand and protected beach habitats was greater than in tidepools which generally supported a more stable community.

Sub-adults and adults of predatory species were collected incidentally in spring and summer. These forms generally avoided the seines.

Surf beach (Table 66)

The surf zone is a relatively harsh environment in which few species and specimens were collected. Large waves often made seining difficult or impossible in the surf. The Atlantic silverside ranked first in frequency of occurrence (60%). Adults were collected year-round. The northern kingfish was second in frequency of occurrence (20%), although it was collected only in summer. All specimens were juveniles. The Florida pompano ranked third (F=11%). It was collected only as a juvenile, and only in summer. The mummichog, white mullet, and windowpane flounder ranked fourth (F=9%) and the sheepshead minnow and striped killifish fifth (F=6%).

Low salinity, mud-sand shore (Table 67)

The banded killifish occurred in 87% of the collections. The next most abundant species, the golden shiner, occurred in 42% of the collections. These species were collected year-round as both juveniles and adults. White perch occurred in 39% of the collections. Most were juveniles. The mummichog ranked fourth (F=29%) but was collected only in the spring and summer. The American eel, chain pickerel, tidewater silverside, and tesselated darter each appeared in 24% of the collections. Most chain pickerel were sub-adults; all of the American eel were juvenile or sub-adults; and most specimens of the tidewater silverside and tesselated darter were adults. In the Mullica River, no species dominated the collections as did the estuarine forage species at higher salinities.

Recurrent Group Analyses (Fager, 1957) were carried out by season for the major seining areas (Fig. 15). All species that were part of a recurrent group or associated were forage fishes common to the shoreline. The mummichog, striped killifish, and Atlantic silverside were members or associates of a recurrent group year-round. These three species were common to abundant in most areas sampled. The fourspine stickleback was a member of a recurrent group in winter and associated to one in spring. It occurred infrequently the rest of the year. The tidewater silverside was associated with the fall and winter recurrent groups. The northern pipefish occurred as an associate to the spring and summer groups. The sheepshead minnow appeared in the fall recurrent group.

Recurrent groups at the 95% confidence level were limited to estuarine forage species. At the 90% confidence level, the tidewater silverside was included in the fall recurrent group. These few species occurred with such irregularity as to preclude being considered with other species.

The Shannon-Weaver Species Diversity Index (McIntosh, 1967; Pielou, 1966a, b) was computed for each station and seasonally for each major area (Table 68). A comparison of indices from Little Egg Harbor stations sampled both during the day and again at night showed greater species diversity at night at two of the three stations. The old Coast Guard Station (Station 13) where the 75-ft seine was used, showed a decrease in diversity at night, perhaps due to occasional large collections of forage fishes. Graveling Point on Great Bay (Station 3) showed more than a two-fold increase in the Species Diversity Index at night. At the Brigantine Golf Course (Station 16), no day-night difference was noted. However, at the cove on Absecon Inlet (Station 23), the index at night was less than half that of the day due to the predominance of the Atlantic silverside collected after dark. Species Diversity at night for Brigantine Inlet (Station 21) was more than six times that of the day value. Night samples were taken only in the spring and summer at this station and contained relatively few specimens of the Atlantic silverside.

Most areas showed highest Species Diversity Indices in spring. The Brigantine surf beach stations, however, showed the highest index in summer samples due to the lack of dominance by any single species and the occurrence of incidentals. During the rest of the year, the Atlantic silverside was the dominant species here and diversity was low. Low diversity was also found at the surf beach station on Long Beach Island (Station 14).

The Brigantine inlet stations showed the highest diversity in spring (1.891). A drop in summer (0.599) and an increase in fall (0.943) were inversely related to numbers of juvenile forage species collected. The lowest index was in winter (0.145) when mostly forage fishes were collected. The Brigantine mud-sand shore had the lowest diversity during summer (0.367), intermediate values during fall and winter (0.757, 0.826), and highest values in spring (1.488).

Great Bay and Little Egg Harbor both had the highest indices in spring (1.858, 1.890) and lowest in summer (1.159, 0.444). Little Egg Harbor had larger differences between seasons, due in part to the lack of a tidepool station. Great Bay had a higher index in fall than in winter (1.469, 1,308) while Little Egg Harbor had higher values in winter than in fall (1.107, 1.528). Large collections of the mummichog, striped killifish, and Atlantic silverside were made during the fall in Little Egg Harbor resulting in low index values.

The Mullica River had the greatest Diversity Index of any area sampled (1.928). This was due in part to the lack of dominance by any species. Spring and summer indices were nearly identical (1.709. 1.714) while fall (1.563) and winter (1.248) values were lower. Other areas, in descending order of Diversity Indices for the year, were Great Bay (1.304), Little Egg Harbor

(0.866), the Brigantine inlet stations (0.847), Long Beach Island surf station (0.673), the Brigantine mud-sand shore stations (0.610), and the Brigantine surf beach stations (0.422).

The lower Diversity Index in Little Egg Harbor versus Great Bay was due in part to the large number of the Atlantic silverside taken in Little Egg Harbor. Over 21,000 Atlantic silverside were taken at Station 2 at Big Thorofare, Little Egg Harbor, in 1972, while under 5,000 were taken at Graveling Point on Great Bay. The Brigantine Golf Course (Station 16) yielded almost 25,000 specimens. The Great Bay stations in general had fewer specimens of the Atlantic silverside than other areas.

During the spring, important sport and commercial species were taken in the shore zone, including the American eel, blueback herring, alewife, Atlantic menhaden, pollock, white perch, bluefish, white mullet, windowpane flounder, and winter flounder. Pollock of about 35 to 40 mm fork length entered the shore zone in late winter and left by late May at a size of 85 to 115 mm. American eel, alewife, white perch, silver perch, weakfish, spot, northern kingfish, tautog, white mullet, windowpane flounder, and winter flounder were common during the summer. Weakfish and silver perch of about 20 to 40 mm total length entered the shore zone in mid-summer. Young of the winter flounder were first collected in June at a size of 25 to 70 mm total length. Numerous other species were taken in the shore zone but none were common (Table 62).

Differences in the catch between areas were noted. Those areas swept by currents produced smaller collections, while flat areas with mud, algae, or eel grass had more species and individuals. Tidepools and mud-bottom stations produced the largest number of killifishes. Juveniles of several species were most common in areas of mud, algae, and eel grass. Tautog, cunner, silver perch, and white perch are examples. Little Egg Harbor produced 10 times more fourspine stickleback than Great Bay. This species occurred mostly in association with eel grass on the west side of Long Beach Island. Eel grass was absent from Great Bay seine stations but Ulva and Fucus were common. Large numbers of silver perch were collected in Great Bay but did not appear as frequently elsewhere. Mullet were more common in Brigantine waters and Absecon Bay than in Great Bay or Little Egg Harbor. During the summer, jacks and northern kingfish were most common in surf areas.

Many of the larger predators were caught at night, possible because of inshore feeding and reduced net avoidance. Pollock, naked goby, seaboard goby and elvers of the American eel were more frequent in night seine hauls.

Results - Large Beach Seine

The 250-ft beach seine was first used in spring. Seven hauls during this period yielded more than 2,543 specimens of 34 species. Some 11,389+ specimens representing 48 species were taken in the summer while 4,035+ specimens of 44 species were collected in the fall (Table 69).

Species composition of beach seine collections was markedly different from that of small seines. The majority of specimens collected by beach seine were adults or larger juveniles. Almost all specimens taken by small seines were juveniles except for forage species. The large beach seine reduced net avoidance by large specimens, but its larger mesh did allow some small specimens to escape.

Two forage fishes, the Atlantic silverside and the bay anchovy, ranked one and two for the year in collections with the 250-ft seine. The spot ranked third due to one large collection of more than 2,570 specimens in summer. Atlantic menhaden, which ranked fourth, occurred predominantly in summer and fall. Bluefish (young) ranked fifth, with the largest number taken in summer.

The number of specimens per collection was relatively low in the spring. Blueback herring, Atlantic menhaden, bay anchovy, striped anchovy, and spot were most abundant. Atlantic menhaden, bay anchovy, striped anchovy, Atlantic silverside, bluefish, and spot were common in summer collections. Atlantic menhaden, bay anchovy, Atlantic silverside, silver perch and spot were common in fall.

Important sport and commercial species common in spring were the blueback herring and winter flounder. Those common in summer included the bluefish, silver perch, weakfish, and spot. The American eel, striped bass, bluefish, and winter flounder occurred commonly in the fall.

Several species collected by beach seine were not taken by other methods (Table 69). Several of these were southern species including the round herring, thread herring, rough silverside, blue runner, round scad, rough scad, and spotted goatfish.

Day and night collections with the large beach seine were made at two stations on Brigantine. Night samples were generally larger and more diverse, although day-night samples for one station on the same day were not taken until December. Seine hauls taken in a protected cove in Absecon Inlet on the south end of Brigantine were much larger both day and night than those in a more swept area of Brigantine Inlet on the north end of the island.

The large beach seine fished at a depth intermediate between shallow areas sampled by small seines and deeper water fished by trawl. This seine has proven effective in collecting a wide variety of species including adult predatory forms and is the only efficient means of sampling in the surf.

OCEAN TRAWL COLLECTIONS

Charles B. Milstein

Materials and Methods

Trawl collections were made in the vicinity of the Site for demersal fishes and macroinvertebrates from 16 February through 20 December 1972. Samples were taken two or three times a month when weather permitted.

A 25-ft semiballoon trawl with a 25-ft headrope and 31-ft footrope made by Marinovich Trawl Company was employed for collections in the ocean. It was equipped with 3-ft x 1.5-ft doors, a 1.5-inch nylon stretch mesh body, and a 1.25-inch stretch mesh codend with a 0.5-inch nylon stretch mesh inner-liner. A funnel-shaped liner of 1.5-inch stretch mesh was laced inside the body just forward of the codend during late August. Fish that passed through the funnel were unable to escape when the net was retrieved. The small mesh in the codend captured some larval fishes as well as juvenile and adult specimens.

A tow line to depth ratio of 6:1 was used for all tows. Boat speed was maintained at approximately 2.0 knots. Each haul lasted for 15 minutes and covered an area of approximately 4,700 m^2. This area was calculated by multiplying the distance covered (about 0.5 nautical miles) by the width of the net when trawling. This width equaled about 16.7 ft or 66% of the headrope length (S. Marinovich, personal communication).

The trawl was designed to collect demersal and epibenthic organisms. Occasionally, juveniles and adults of some semi-demersal and pelagic species constituted a major portion of a particular catch. Schools of species such as the Atlantic herring, Atlantic menhaden, bluefish, striped bass, and Atlantic mackerel generally avoided the trawl or were distributed in the water column above the trawl. The location and relative size of surface schools of fishes were recorded.

The ocean from Little Egg and Beach Haven inlets to an area seaward of the proposed Site was divided into 11 regions which included a total of 64, one square mile quadrats for replicate sampling and analysis (Fig. 3). Each region is defined by some combination of the following: depth, permanent buoy, nautical distance from the inlets, or distinct marine topography.

The 11 regions are delimited below (see Fig. 3). A description of sediment types in these areas is considered in the discussion on SEDIMENTS.

1. The "Ridge" (sections 5251-5253) is located 2.5 nautical miles southeast of Little Egg Inlet and forms the seaward margin of the Site. The crest of the Ridge lies at a depth of 25 ft, mean low water (MLW).

2. The "Site" (sections 5254-5256) extends from the landward margin of the Ridge shoreward to the Little Egg Inlet bell buoy, which is designated BW "LE" Mo (A) Bell on Coast and Geodetic Survey charts. Depth in the area ranges from about 35 to 45 ft, MLW.

3. The region "Landward of Site" (sections 5257-5259 and quadrat 5150) extends from the landward margin of the Site shoreward to a depth of approximately 10 ft, MLW.

4. The "Inlet" (quadrats 5040-5060) encompasses the area off Beach Haven and Little Egg inlets between the south end of the Holgate Peninsula and the north end of Little Beach. Depth ranges from about 5 to 15 ft, MLW.

5. The "Nearshore" (5020, 5030, 5070, and 5080) includes the area in and seaward of the surf zone off the Holgate Peninsula and Little Beach out to a depth of approximately 15 ft, MLW.

6. The region "North of Site" (5230, 5240, 5130, and 5140) includes a 4 square mile area north of the Site. Depth ranges from approximately 15 to 50 ft, MLW.

7. The region "West of Site" (5260, 5270, 5160, and 5170) includes a 4 square mile area west of the Site. Depth ranges from about 10 to 40 ft, MLW.

8. The region "East of Site" (5430, 5440, 5330, and 5340) includes a 4 square mile area east of the Site. Depth ranges from about 35 to 60 ft, MLW.

9. The region "Seaward of Ridge" (5350 and 5450) extends from the seaward margin of the Ridge seaward approximately 2 miles. Depth ranges from about 38 to 60 ft, MLW.

10. The region "South of Site" (5460, 5470, 5360, and 5370) includes a 4 square mile area south of the Site. Depth ranges from approximately 30 to 50 ft, MLW.

11. "Offshore" (5510-5600) includes the area seaward of regions 8-10 above.

Generally, six to eight hauls were made per sampling trip depending on weather conditions and the time needed to process each haul. Regions not sampled during one trip were generally sampled on succeeding cruises. Each haul was made in a general northeast or southwest direction to follow defined depth contours and cover a narrow depth range. This procedure afforded later analysis of species distribution by depth.

Large catches were generally subsampled and a representative size series of each species preserved. The remaining individuals of each species were counted, often measured, and then returned to the water. Beginning with the 16 November cruise, the total weight of each species was recorded from several separate hauls.

The Shannon-Weaver Species Diversity Index as discussed in McIntosh (1967) and Pielou (1966a, b) was applied to the catch data.

Results

Data for individual collections are recorded in Appendix Tables 13 to 15. The catch by month of all fishes is presented in Table 70 and that by season and for the 1972 total catch in Table 71. Species distribution by depth for each season and combined for 1972 is presented (Table 72). Depth intervals of 5 to 19 ft, 20 to 39 ft, 40 to 59 ft, and 60 to 69 ft, as well as the Ridge, were chosen for comparison. The Ridge, at a depth of 25 ft MLW, was distinct from the surrounding areas and was thus presented separately.

In the results which follow, N equals the number of specimens; and N/Coll. equals the number of specimens per collection, that is, the total number of specimens divided by the total number of collections. F equals the frequency of occurrence of a species, that is, the number of collections in which the species appeared; and N/F equals the number of specimens per collection in which the species appeared. A total of 69 species, more than 53,554 specimens, and 332.6+ specimens per collection were taken in 161 samples in 1972 (Table 71); four additional hauls were aborted. The first 10 species ranked by numerical abundance were the bay anchovy (66.2% of the total catch), red hake, silver hake, spotted hake, weakfish, American sand lance, windowpane flounder, butterfish, alewife, and northern searobin. These 10 species comprised 89.6% of all specimens collected in 1972. In addition, all of the above except the weakfish, and northern searobin occurred in all seasons with varying frequency. The bay anchovy and alewife are generally pelagic; they were nevertheless at times highly susceptible to capture by the bottom trawl. Only five species other than the eight mentioned above were taken in all seasons; these were the little skate, blueback herring, northern pipefish, smallmouth flounder, and winter flounder.

The first 10 species in frequency of occurrence (F) in trawl collections in 1972 (Table 71) were the windowpane flounder (taken in 125 hauls), red hake (108 hauls), bay anchovy (92), spotted hake (77), winter flounder (75), northern searobin (70), smallmouth flounder (70), silver hake (66), little skate (61), and butterfish (59). Winter species such as the longhorn sculpin were perhaps poorly represented because of the fewer number of winter hauls taken.

Patchiness in distribution, schooling behavior, and temporal distribution will influence N/F (Table 71). The bay anchovy generally dominated collections in which it occurred and thus ranked first numerically as well as by N/F. Similarly, the red hake and silver hake were often the dominant species in collections. As a result, the red hake was ranked two and three and the silver hake three and five by N and N/F, respectively. The American sand lance, however, was sixth numerically but second by N/F due to one large collection of the species. Other species such as the Atlantic menhaden and Atlantic mackerel were ranked 19 and 27 by numerical abundance, respectively, but number 8 and 4 by N/F. Young menhaden were common in winter, rare in spring and fall, and absent in summer collections. The more demersal habit, and the possibly reduced activity of young menhaden and other herrings during the cold months apparently made them more accessible or susceptible to the trawl than were the pelagic adults. All 60 Atlantic mackerel young taken in 1972 were collected in two spring samples.

The total specimens per collection (N/Coll.) showed a marked decline when passing from inshore depths of 5 to 19 ft, to deeper seaward depths of 40 to 69 ft (Table 72). Collections in depths of 5 to 19 ft produced 667.3 N/Coll. or almost twice that of the next most productive region of 20 to 39 ft in depth (353.8+). The 1972 total N/Coll. for the ridge (124.8+) was lower than the 20 to 39 ft or 60 to 69 ft depths (179.5) but greater than seaward depths of 40 to 59 ft (119.2). If the one large catch of over 1,000 adult American sand lance on the Ridge is excluded, the N/Coll. from the Ridge would be reduced to 81.3+. This low N/Coll. for samples made along the Ridge axis may have been due in part to increased wave action there and reduced numbers of invertebrate prey species as discussed in the section on BENTHIC INVERTEBRATES. The poor catches on the Ridge are in contrast to concentrations of demersal fishes reported on two ridges off North Carolina by Struhsaker (1969).

Some 50 species were collected in depths of 5 to 19 ft and 59 species in depths of 20 to 39 ft in 1972 (Table 72). However, the greatest number of collections (73) was made in the latter depths to concentrate sampling efforts at the Site and in peripheral areas. The few species (12) collected at depths of 60 to 69 ft reflect the few collections (2) made in this deeper area considerably beyond the Site.

Young and adult bay anchovy dominated catches in depths of 5 to 19 ft, 20 to 39 ft, and on the Ridge (597.8+, 220.7+, and 33.9+ N/Coll., respectively). In depths of 40 to 59 ft, the number of bay anchovy dropped off abruptly to 1.1 N/Coll. None were taken in deeper water. Young and juvenile red hake, spotted hake, and silver hake were common to abundant throughout the depths sampled except on the Ridge. Young and juvenile weakfish and butterfish were numerous at depths of 5 to 39 ft and on the Ridge. The N/Coll. for these species declined at depths of 40 to 59 ft. Windowpane flounder and northern searobin were numerous at depths of 20 to 59 ft and less common in the shallow depths. Young, juveniles, and adults of the windowpane flounder were well represented in the samples while most northern searobin collected were adults. The alewife was common at depths of 20 to 69 ft excluding the Ridge; fewest specimens were taken in depths of 5 to 19 ft. Most of the specimens were young or juveniles.

Ninety-nine percent of the sand lance were collected on the Ridge. The coarse sand composition of portions of the Ridge (Fig. 11) may provide a preferred habitat for this burrowing species. Large striped bass taken by sport fishermen on a smaller ridge off Brant Beach, Long Beach Island, were found to be feeding heavily on sand lance. Sand lance eggs were collected in benthic Ponar grab samples on the Ridge.

The diversity index for all 1972 collections was 1.64. Species diversity was about equal during winter (2.24) and spring (2.46). It declined to 1.01 in summer, largely due to dominance by the bay anchovy, and then increased slightly in fall (1.21).

Species diversity was lowest (0.65) in depths of 5 to 19 ft due to concentrations of bay anchovy there. Diversity increased for collections made in deeper water and was highest (2.37) for samples in depths of 40 to 59 ft.

Seasonal differences of diversity in collections in depths of 5 to 19 ft were largely influenced by variations in seasonal abundance of the bay anchovy.

During winter, diversity was about equal throughout the depths sampled and ranged from 2.01 to 2.24. It was slightly lower on the Ridge. In spring, diversity increased in all areas except in depths of 5 to 19 ft; it decreased there by about one half to 1.01. Species diversity decreased in all areas in summer, particularly at depths of 5 to 19 ft (0.30). By fall, when catches of the bay anchovy declined, diversity at depths of 5 to 19 ft rose to 1.18 while at depths of 20 to 39 ft and on the Ridge, diversity remained about equal to that of summer. Diversity at depths of 40 to 59 ft declined in the fall.

Seasonal summaries for 1972 follow. Values for N, N/Coll., F, and N/F for all collections from the vicinity of the Site combined are given in Table 71. Values for N/Coll. for the depth ranges described above and the Ridge appear in Table 72. Ranges of physicochemical parameters by season for these areas are given in Table 73.

Winter

A total of 26 species, 2,999 specimens, and 143.7 N/Coll. were taken in 16 trawl samples from 16 February through 21 March (Table 71). No collections were made in the vicinity of the Site in January. The least species and N/Coll. in the vicinity of the Site (Fig. 16) were taken in February when surface temperature ranged from 3.5 to 4.0 C (38.2 to 39.2 F). Species diversity increased slightly from February (1.89) to March (2.06).

The first five species in order of numerical abundance in winter were the red hake, alewife, blueback herring, Atlantic silverside, and Atlantic menhaden. They comprised 74% of specimens taken in winter; the red hake and alewife alone comprised 48% of all specimens. These five species were represented predominantly by young (0+ year class) and juvenile specimens. The first four species occurred with the greatest frequency (F) in winter collections. The Atlantic menhaden appeared in four samples, and at times was numerous. Young of the red hake were probably recruits from offshore spawning and apparently utilized inshore waters as a nursery. The other four species were overwintering in inshore bottom waters. Several flatfishes, particularly juvenile and adult windowpane flounder and winter flounder, were common. Both species are year-round residents in the vicinity of the Site. Adults of the winter flounder moved from offshore grounds to the area of the Site in late fall and remained there throughout the winter. It spawned in the inshore ocean and bays during winter and early spring. Large numbers of adults were collected later in the spring as they moved out of the bays.

The species composition of one collection made off Harvey Cedars, Long Beach Island on 15 January and seven collections made on 23 February (Appendix Table 14) was similar to that at the Site in February (Table 70).

Important species consisted of the various herrings, hakes, Atlantic silverside, windowpane flounder, and winter flounder.

Several species were taken only or almost exclusively in winter. These included the spiny dogfish, threespine stickleback, grubby, and the sea snail, *Liparis inquilinus* (an undescribed species).

Far greater N/Coll. were collected during winter in depths of 20 to 39 ft and 60 to 69 ft than in other depths. Hauls from depths of 5 to 19 ft produced the least N/Coll. Collections from depths of 20 to 39 ft yielded large numbers of several species of herring (*Alosa* spp.) and hakes (*Urophycis* spp. and *Merluccius*). Moderate numbers of windowpane flounder and winter flounder were also taken there. Small forage fishes such as the Atlantic silverside and northern pipefish were common. The former species was taken in all depths, but the latter species was almost exclusively captured at depths of 5 to 39 ft. Marsh grasses, eel grass, algae, and detritus from the bays were often common at these shallower depths.

Spring

A total of 53 samples from 6 April through 26 June yielded 38 species, 8,080 specimens, and 152.5 specimens/collection (N/Coll.). The N/Coll. increased slightly from winter to spring, while the number of species taken increased substantially (Table 71).

In April, winter species were replaced by spring and summer forms (Tables 11 and 70). The N/Coll for April (134.6) was below that of March (159.5), May (165.4), or June (160.4). Approximately an equal number of species (Table 70) was collected in April (29) and May (31) and fewer in June (22).

Surface water temperature increased in April (Table 73) and ranged from 6.0 C (42.8 F) to 11.0 C (51.8 F). In May, values ranged from 10.5 to 17.0 C (50.9 to 62.6 F). However, the warmest bottom temperature recorded in May (Table 73) was only 13.0 C (55.4 F). By the end of June, surface and bottom temperatures reached 19.5 and 15.5 C, respectively (67.1 and 59.9 F).

In spring, the five most numerous fishes were adults of the bay anchovy; young, juvenile, and adult red hake and spotted hake; and juvenile and adult windowpane flounder and winter flounder (Table 71). All of these occurred in at least 64% of the spring collections; the windowpane flounder (F=46), red hake (38), and winter flounder (37) occurred most frequently. The red hake, clupeids, northern pipefish, Atlantic silverside, and yellowtail flounder declined in N/Coll. markedly during the spring. In contrast, a wide range of species either first appeared (17 species) or substantially increased in N/Coll. (11 species). The smooth dogfish, white hake, butterfish, northern searobin, and striped searobin were notable in the former group. The little skate, bay anchovy, silver hake, spotted hake, and several flounder species were important in the latter group. Silver hake and spotted hake recruits from offshore grounds gradually replaced the red hake which had departed from Site waters by early summer.

The greatest N/Coll. of 280.1 in spring was from the shallowest depths, 5 to 19 ft (Table 72). This was due largely to substantial catches of the bay anchovy. N/Coll. decreased to 166.7 and 111.6 at depths of 20 to 39 ft and 40 to 59 ft, respectively; lowest N/Coll. and the fewest species were from the Ridge.

Summer

Some 46 trawl hauls from 7 July through 18 September produced 49 species, more than 25,140 specimens and 546.5+ N/Coll. The most species (36) were taken in July and the greatest N/Coll. (1,442.4+) in September (Table 70). A marked decline occurred in the N/Coll. from July (205.9+) to August (56.5). Species diversity increased from 1.74 in July to 2.52 in August. By August, a large number of demersal fishes had moved out of the Site area. Pelagic and semi-demersal forms which were common at this time generally were not taken by the bottom trawl. In addition, greatly increased water clarity during the summer months, as indicated by secchi readings up to 23 ft, probably contributed to net avoidance by some species. Predation by large schools of bluefish and weakfish may have also contributed to reduced catches of forage species during the summer.

Fishes such as the bay anchovy and various drums began to move out of the bay systems in September (Fig. 16). These migratory species were often collected in large numbers and contributed significantly to the large September catch and the low diversity (0.57).

The five most common species in summer were the bay anchovy, American sand lance, weakfish, spot, and butterfish. They comprised 91% of all specimens collected. Specimens of the weakfish, spot, and butterfish were largely young (0+ year class). The smooth dogfish (F=25), northern searobin (32), striped searobin (25), and windowpane flounder (32) also appeared frequently.

Twenty-two species of fish occurred for the first time in 1972 during summer. These included a number of migratory forms such as the striped anchovy, several drums, and the Atlantic mackerel (0+ year class).

Some transient subtropical and tropical skates, rays, and jacks were taken only in July and August (Table 70) when bottom water temperatures (Fig. 16

reached maximum values of 23.5 to 24.0 C (74.3 to 75.2 F). Nine species were taken only in summer samples; the majority were warm water strays. A total of 49 species was taken during summer (Table 71).

Ten species showed increased values of N/Coll. in summer compared with their values in spring. The most important species in this category included the smooth dogfish, bay anchovy, weakfish, butterfish, striped searobin, and northern searobin. Conversely, 27 species had reduced values of N/Coll. These were mainly winter and spring forms such as the red hake which generally moved from warm inshore to cooler offshore waters.

The shallowest depths, 5 to 19 ft, produced the greatest N/Coll. (1,308.7+). This was primarily due to large catches of the bay anchovy off Little Beach (Table 72). The N/Coll. decreased substantially from collections in inshore areas to those in depths of 40 to 59 ft. A series of seven, 10-minute collections was made in early August with the 16-ft semiballoon trawl usually used in bay sampling. Hauls were conducted in the inlets, nearshore, and shallow areas just seaward of these two regions (Appendix Table 13). The bay anchovy dominated the catches and small, young weakfish were common.

Fall

A total of 46 collections made from 2 October through 20 December produced 50 species, more than 18,035 specimens and 392.0+ specimens per collection (Table 71). The first five species numerically were the bay anchovy, red hake, silver hake, butterfish, and northern pipefish. The first three species appeared in 59% or more of the collections. The five species together comprised 93% of all specimens taken in the fall. Samples in October (Table 70) yielded the highest N/Coll. (698.2+) and the lowest species diversity (0.40). December samples had the smallest N/Coll. (158.6) and a diversity of 1.33. The number of species collected during each fall month was about equal and ranged from 31 in October to 34 in November.

The egress of migrating species from the bays during September and October contributed to the large N/Coll. in inshore ocean waters. The great majority of the specimens were the ubiquitous bay anchovy (Fig. 16). Other migrants included species such as the silver perch and weakfish. The N/Coll. declined from October through December as species which were common in summer and fall left the area.

The transition from summer to winter species was gradual. This was in contrast to a sharper shift described in April from winter to spring-summer species. This transition reflects the gradual decrease in water temperature in the fall compared to the rapid increase in temperature in the spring (Figs. 6 and 16). Some 15 species taken in the summer were absent in fall collections. Nine of these were subtropical and tropical transients or strays.

Fifteen species showed increased values of N/Coll. from summer to fall, notably the little skate, several herrings, silver hake, red hake, and northern pipefish. These species were characteristic of the demersal community of cooler waters during fall, winter, and spring. Another 16 species showed decreases. Important in this group were the smooth dogfish, bay anchovy, spotted hake, white hake, scup, several drums, northern searobin, and striped searobin.

The largest number of specimens per collection (549.3+) and species (42) were taken in depths of 20 to 39 ft. Collections on the Ridge yielded the least N/Coll. (59.3) and species (16). The bay anchovy dominated in catches from depths of 5 to 39 ft.

Weights of Fishes

The total weight of all specimens of each species from several separate trawl collections during a cruise was taken beginning on 16 November (Table 74). Specimens from six collections taken in November and eight taken in December were weighed. Nine collections were selected for analysis from hauls made at depths of 20 to 39 ft and five collections from depths of 40 to 59 ft. The weight of each species provided another means to evaluate the significance of a species in the demersal fish community. In addition, the total weight of the catch can be used to calculate conservative estimates of the standing crop of demersal fishes. An approximate three fold increase occurred in the weight of the catch from November (3.99kg) to December (11.93kg). This was due to greatly increased catches in December of the little skate, silver hake, red hake, and longhorn sculpin and the capture of several large adult goosefish.

Other than the bay anchovy, a semi-demersal schooling species, the red hake was numerically (Table 70) and by weight (Table 74) the dominant demersal species in the November collections. Ranked by weight, the next four fishes were the windowpane flounder, weakfish, little skate, and spotted hake. However, the little skate and spotted hake were not important numerically. In December, the red hake was most numerous and second in order by weight. Conversely, the silver hake ranked first by weight and was second in order by number of specimens. The next three species by weight were the spiny dogfish, goosefish, and alewife. Numerically, the spiny dogfish and goosefish were insignificant but the alewife was common.

Water Temperature and Distribution of Fishes in the Vicinity of the Site and Little Egg Inlet

Temporal distribution patterns and the migrations of fishes are in general related to water temperature. Occurrences and movements of fishes in the vicinity of the Site based on the trawl data, are treated here in relation to 1972 water temperatures. Some of the species which displayed well defined movements which correlated with water temperature are discussed below in phylogenetic order.

Of the sharks, skates, and rays collected, only the smooth dogfish and little skate occurred frequently in 1972. The dogfish was first taken in mid-May, was common until early October, and was absent by the end of October when bottom temperature was 12 C or 53.6 F (Appendix Table 15). The little skate occurred in winter, spring, and early July. It was absent during the period of high summer water temperatures and reappeared in mid-October when bottom temperature decreased to 14 C (57.2 F).

The bay anchovy was numerous in early April when surface temperature was 6.5 to 7 C or 43.7 to 44.6 F (Appendix Table 15); N/Coll. increased as water temperature rose sharply in May. By June there was a marked decrease in N/Coll. due possibly to movement into the bays, natural mortality, and predation. Large catches of this species were made occassionally throughout July and August, particularly Nearshore and in the inlets. By early September the N/Coll. increased almost 100 fold to 1,286.6+ from the August value of 14.3. A major movement from the bay areas coincided with decreasing water temperature in the latter half of August (Fig. 6 and Appendix Table 15). Large catches were made in the ocean until the end of October. Young (0+ year class) of the bay anchovy made up a large part of the September and October collections. The bay anchovy was generally absent from the vicinity of the Site after mid-November when the water temperature declined to about 10 C.

Several species of hake were alternately abundant. The red hake ranked first numerically of all species collected during the winter.

in the vicinity of the Site. As N/Coll. for this species decreased in spring, that for the silver hake and spotted hake increased. Red hake and silver hake were rare in Site samples in July after bottom temperature reached about 15 C (59 F); they reappeared in mid-to late November when bottom temperature was about 9 C. N/Coll. for the spotted hake and white hake rose during June and early July; it declined at the end of July when the bottom temperature was about 18 C (64.4 F). The white hake first appeared in mid-May and was common by the end of May when the bottom temperature was approximately 12.5 C (54.5 F). Some spotted hake and white hake were found again in mid-November.

All those members of the drum family which were common in 1972 arrived in the vicinity of the Site in late spring to early summer except the weakfish which first appeared in April. Adult weakfish were regularly taken by sport fishermen in April and May but generally were not collected by trawl at that time. Weakfish and silver perch were occasionally collected in the vicinity of the Site in early July; the spot and northern kingfish appeared by late July. By late August, young specimens of these four drums began moving out of the bays and by mid-September when bay bottom temperature was 20 C (68 F), the migration was fully underway. It continued into late October. Stragglers composed of young weakfish and silver perch were taken throughout the fall but the major offshore and southerly movement was completed by mid-November. Bay and ocean bottom water temperatures during mid-November were 9 to 10 C, respectively.

The butterfish first appeared regularly at the end of May, was common in summer, and most numerous from mid-September to early October after which few were collected (Table 71).

Northern searobin and striped searobin occurred frequently in collections from the ocean. The N/Coll. for the northern searobin was about equal in spring and summer whereas the N/Coll. was substantially greater for the striped searobin in the summer. The former began to appear regularly in late April samples when the surface temperature was about 10 C; the latter was first taken consistently at the end of May when bottom water temperature reached 13 C (55.4 F). The largest N/Coll. for the northern searobin occurred in June and that for the striped searobin in September. N/Coll. for each species declined sharply in October although some specimens of northern searobin were collected in the vicinity of the Site through November and some striped searobin were taken through December.

The longhorn sculpin occurred in winter, spring, and fall catches but was absent in summer. N/Coll. increased from February through April, dropped sharply in early May and by mid-May this species was absent. It reappeared in mid-November and was taken regularly through the rest of the fall.

Several species of flounder were year-round residents in the vicinity of the Site. The greatest N/Coll. of smallmouth flounder and windowpane flounder were taken in spring. The winter flounder was collected in all months except September; however, a far greater N/Coll. appeared in winter and spring than in other seasons. The largest collections were made in May (11.4 N/Coll.) and June (8.4) as adults moved out of the bays. By early July, bay bottom waters had reached 20 C and most adults had left the vicinity of the Site. Young and juveniles, however, were concentrated in the shore zone of the bays in late spring and summer.

The summer flounder was absent in winter. It appeared in mid-April and was taken infrequently in summer and fall in collections from the ocean. During summer and fall it was common in the bays and inlets and was an important part of the sport catch. The yellowtail flounder occurred predominately in winter and was absent after the beginning of May when the surface temperature was about 10.5 C (50.9 F). It appeared again in late November when surface and bottom temperatures were about 9 C.

Discussion

No previous year-round, intensive sampling efforts have been conducted off the New Jersey coast to determine the temporal and spatial distribution of fishes. Most studies of marine fish populations have been made either farther offshore on the continental shelf or in inshore waters north or south of New Jersey.

Fowler's (eg 1906, 1937, 1952) studies over more than 50 years in New Jersey waters include some 90 publications on the State's marine and estuarine fishes. However, this work was systematic in nature and was not based on regular year-round sampling nor was it designed to explore the ecological interactions of the inshore fish community. His studies do provide an extensive list of inshore and offshore species which may occur in this area. Unpublished trawl survey data from cruises of the National Marine Fisheries Service vessel Delaware off the New Jersey coast may provide comparative data for offshore and inshore stocks when the information becomes available.

Year-round investigations of demersal fish communities have been conducted for southern New England by Merriman and Warfel (1948) and Richards (1963). The species composition of their catches was similar to ours.

Merriman and Warfel (1948) analyzed monthly commercial catches of the winter flounder trawl fishery off Rhode Island and Connecticut from 1943 to 1946. The number of species, specimens, and weight by species was greatest in summer and fall and least in winter and early spring. This corresponds to our findings for species and specimens. They found that most species were taken when migrant forms occurred in the study area. Some they classified as permanent residents, but noted that components of these populations may be migratory. In the present study, the bay anchovy, hakes, smallmouth flounder, windowpane flounder, and winter flounder were present in some stage through most of the year.

Richards (1963) surveyed demersal fishes in Long Island Sound and compared those taken at sand- and mud-bottom stations in depths of 18 and 51 ft over a 2-year period. The demersal community showed the same seasonal variations in number and type of species and number of specimens as that described for the vicinity of the Site. In general, the former fauna was comprised mostly of either small species or juveniles of larger species. The fish community at the Site was well represented by larger species and adult forms as well as juveniles. Populations of some species such as the northern searobin, striped searobin, longhorn sculpin, and yellowtail flounder were comprised mostly of adults. Apparently the vicinity of the Site supports demersal fishes which utilize the area for spawning and as nursery and feeding grounds.

Richards (1963) reported that the demersal community of Long Island Sound and southern New England was largely dominated by sharks, skates, rays, hakes, sculpins, and especially pleuronectids. In the vicinity of the Site the above fishes and the herrings, bay anchovy, drums, butterfish, searobins, and bothids were important components of the demersal community.

Tyler's (1971) study of demersal fishes off New Brunswick, Canada demonstrated spring (April) and fall transition periods as noted in the present study.

Dahlberg (1972) considered those beach and inshore ocean regions in Georgia which were affected by estuarine outflow to be part of an estuarine-beach complex. He examined seven coastal habitats ranging from marine to low salinity areas and found the most species in the beach system. The large number of species found in the beach environment was due to occurrences of marine as well as estuarine forms.

The areas designated as Nearshore and Inlet in this study are part of the estuarine system and turbid bay water was apparent. The shallowest depths sampled in the vicinity of the Site (5 to 19 ft) included the Nearshore-beach area and yielded the second greatest number of species of all the depth ranges sampled. Among the fishes taken there were the oyster toadfish, northern sennet, and hogchoker which were typical of estuarine collections.

One of the major problems in analyzing trawl data is the large variability between samples. In their analysis of repeated hauls for inshore demersal fishes, Barnes and Bagenal (1951) reported that to be significantly different, the catch in one haul had to be three times that of another. Variations in the abundance of species between hauls were large enough to mask differences in the catch composition between the two habitats Richards (1963) studied. Taylor (1953) suggested that the variability in mean catch per haul was the result of the "basic heterogeneous distribution of the numbers of fishes." He pointed out that this variability in mean catch might be decreased by shortening haul duration and decreasing trawl size.

In the present study a 15-minute tow time was selected to provide a sample from a relatively uniform area. A series of collections could be completed within a short time span over a variety of different areas and thus reduced the effects of short term species movements in the vicinity of the Site. The 25-ft trawl was smaller than those trawls used by several workers cited above. The smaller samples taken in this study facilitated rapid processing of each collection. This effectively increased the number of collections which could be completed and the number of parameters recorded for each species in each haul.

PELAGIC AND SEMI-DEMERSAL FISHES

Observations of schooling species were recorded during day cruises in the vicinity of the Site. Additional information was obtained from charter boat captains who regularly fish the area.

Northward migrating Atlantic mackerel were first found in mid-April, and were distributed from approximately 2 to 20 miles offshore of Little Egg Inlet. Surface water temperature in the vicinity of the Site at that time was approximately 7 to 9 C (45 to 48 F). These mackerel, and the striped bass which arrived later, were extensively fished by sport fishermen. The Atlantic mackerel was found off the coast for several weeks.

Schools of northward migrating striped bass generally appeared in the vicinity of the Site during April when surface temperature reached approximately 10 C (50 F). Schools of striped bass migrating south reappeared in late September near the Site when surface temperature was approximately 20 C (68 F). Small striped bass ranging from about 400 mm to 430 mm fork length (FL) were common in the vicinity of the Site during October and remained until about mid-November when surface temperature had declined to 10 C (50 F). Large adult striped bass up to 35 lb. and ranging in size from 770 mm to 1,040 mm FL, were taken by sport fishermen on a ridge off Brant Beach, Long Beach Island. These fish concentrated near this ridge for a period of a few weeks. Many smaller striped bass entered Great Bay in the fall to overwinter in the Mullica River. Some remain in the study area throughout the year.

Schools of the Atlantic menhaden were first observed in the vicinity of the Site on 17 June when surface water temperature was 21 C (69.8 F).

Adults were found in the ocean and bays as early as April. Schools of Atlantic menhaden were recorded frequently from 17 June through August. The frequency of occurrence of schools decreased in September and the final siting was on 2 October when surface water temperature was 16 C (60.8 F). Charter boat captains reported that menhaden were more numerous in 1972 than in the past several years.

Schools of the bluefish appeared in May and were common to abundant until late October when surface water temperature was about 12 C (53.6 F).

The weakfish occurred in the area of the Site from about mid-April through mid-November. During July and August, large schools were frequently observed feeding actively at or near the surface. During September, schools were usually distributed near the bottom. Surface water temperature during September was about 20 C (68 F) and the bottom temperature was slightly cooler, 18 to 19 C (64.4 to 66.2 F).

GILL NET

Seven gill net collections were made in Great Bay from early April to mid-May (Appendix Table 23). The nets were fished from the surface to a depth of 10 ft. The total length of netting used varied from 640 to 720 ft. The net included four, 180-ft sections of 5, 5 1/8, 5 1/8, and 5 1/4-inch mesh, and one, 100-ft section of 3 1/4-inch mesh. The main portion of the catch consisted of 49 alewife, 31 striped bass, 20 American shad, and 18 Atlantic menhaden. The American shad were all adults and a few males were ripe. However, there is no evidence of local spawning.

On 27 June 1972, a gill net 750-ft long and 15-ft deep was set in the area of the Site (Appendix Table 23). The net was fished on the bottom in about 40 ft of water. The catch consisted of 73 smooth dogfish, 66 Atlantic menhaden, 7 hickory shad, 2 weakfish, 1 bluefish, and 1 winter flounder.

BAY TRAWL COLLECTIONS

F. Joseph Margraf and Donald J. Danila

Introduction

A systematic trawl program was initiated on 22 February 1972 in the Mullica River-Great Bay estuary and neighboring bays. Although the trawl was designed to sample epifauna and demersal fishes, some semi-demersal and pelagic fishes were taken.

The four major sampling areas were subdivided into zones to facilitate replicate sampling and analysis of catch data. These included Little Egg Harbor (9 zones), Great Bay (12 zones), Mullica River (5 zones), and the intracoastal waterway and back channels between Brigantine and Absecon Inlets (10 zones). A description and location of each zone are given in Table 75 and the location of each is shown in Figure 1. The data for each collection including nine trawl collections in Barnegat Bay are given by sampling area in Appendix Tables 16-21.

Each bay system was divided into three general areas for analysis of distributional differences within bay systems. In Little Egg Harbor and Great Bay these areas are referred to as the inner bay, that is, the generally shallow area farthest from the ocean; the mid bay, the somewhat deeper area between the inner bay and inlets; and the inlet. The Brigantine system was divided into the intracoastal waterway, which is located just east of the Brigantine Wildlife Refuge; Obes Thorofare and Bonita Tideway, which are just west of Brigantine Island; and the inlets, which include both Brigantine and Absecon inlets. Mean monthly temperatures for each bay area are presented in Figures 7 to 9 and discussed in the section entitled Physicochemical Data.

The statistical tests used in the analysis of the catch data were the Shannon-Weaver Species Diversity Index, as discussed in McIntosh (1967) and Pielou (1966a, b); the Distance Measure, as discussed in McIntosh (1967); and the Recurrent Group Analysis of Fager (1957).

Materials and Methods

A 16-ft semiballoon trawl, manufactured by Marinovich Trawl Company, was used for all bay collections. The nylon net had a 1.5-inch stretch mesh body and a 1.25-inch stretch mesh codend fitted with a 0.5-inch stretch mesh innerliner. The trawl had a 16-ft headrope and 19-ft footrope and doors of 24 x 12 inches.

Ten minute bottom hauls were made at a constant engine RPM in each zone. Boat speed was generally between 2.0 and 3.0 knots depending on the current and wind. A towline length to water depth ratio of 5:1 was maintained for each haul. An average haul covered a bottom area of approximately 2500 m^2 (see section on Fish-Ocean Trawl).

Results

A total of 554 hauls yielded more than 45,000 specimens of 64 species. The five most abundant fishes taken (Table 76) were the bay anchovy (35,415+), Atlantic silverside (2,927), white perch (2,118), silver perch (942), and winter flounder (782).

The bay anchovy, an important forage fish, was taken in large numbers in all seasons except winter when only three were collected. It was abundant in summer (157.1 specimens per collection), when it comprised 93% of the total catch. Young (0+ year class) first appeared in early summer, but were not numerous until August. Approximately 75% of the bay anchovy were taken in the inner bay areas. The species was particularly common in the intracoastal waterway behind Brigantine.

The Atlantic silverside, another forage fish, was collected throughout the year. The greatest number of specimens was taken in fall after the species moved into deeper water. Trawl collections in Little Egg Harbor and Brigantine yielded the greatest numbers.

The white perch was also taken throughout the year. The largest number were captured in the Mullica River. During the colder months this species moved into higher salinity areas of the lower Mullica River and parts of Great Bay. Very few were taken in Little Egg Harbor and Brigantine where fresh water inflow was low. Most of the white perch taken from Brigantine came from the zone adjacent to Great Bay. It is an important sport and commercial species and large numbers are taken by sport fishermen in the Mullica during winter and early spring.

The silver perch is a sport fish which utilized the bays for spawning and as a nursery. The adults were first taken in trawl collections in late May and the young appeared in August. Most were taken in the inner and mid-bay zones.

The winter flounder is a popular sport species caught commonly in the bays in March and April. It spawns in the bays and ocean in late winter. Adults were abundant in trawl collections during April and early May, but were absent from June samples. During June, young of approximately 40 mm total length appeared in collections. Young and some juvenile fish, probably 1+ year class, were taken in the bays throughout the year. The largest numbers per collection came from the mid-bay zones in Little Egg Harbor, and from the intracoastal waterway and Obes Thorofare-Bonita Tideway zones in Brigantine.

Limited numbers of several other commercial and sport fishes were collected by trawl. These included the alewife, American shad, Atlantic menhaden, striped bass, black sea bass, bluefish, scup, weakfish, spot, tautog, and summer flounder. The alewife and American shad were occasionally common during the spring when substantial numbers were collected by gill net. Large numbers of striped bass were taken by sport fishermen in the Mullica River and Great Bay in the spring and near the inlets in the fall. Sport fishing records also indicated that black sea bass, bluefish, scup, weakfish, spot, and summer flounder were at times common. Schools of Atlantic menhaden were often sited at the surface in the bays during the warmer months. Most of these fishes are semi-demersal, pelagic, or fast-swimming species which generally are not captured by the trawl.

Bay trawl catch statistics for 1972 are summarized in Table 77. The greatest number of species (49) and specimens per collection (168.8+) was taken in the summer. Collections made in spring and fall yielded slightly fewer species, 39 and 44 respectively, and fewer specimens per collection (37.9+ and 43.4+). Hauls made during the winter yielded 26 species and 21.2 specimens per collection. The bay anchovy was abundant during warmer months. When specimens of this species were not included in the seasonal totals, the number of specimens per collection was as follows: winter (21.2 vs 21.2), spring (12.4 vs 37.9), summer (11.7 vs 168.8), and fall (26.7 vs 43.4).

The greatest species diversity was found in winter (2.02) and the lowest in summer (0.43). Spring (1.45) and fall (1.72) values were intermediate. The Distance Measure was also applied to the seasonal data. The results seem to indicate shifts in community structure. The Distance values for seasonal comparisons were 0.75 for winter-spring, 0.29 for spring-summer, 0.64 for summer-fall, and 0.54 for fall-winter. A comparison of winter and summer communities yielded a value of 0.99 indicating almost no similarity in community structure. The spring-fall value was 0.42.

The seasonal catch statistics for each bay showed trends which were generally similar to those of the 1972 combined statistics. However, Great Bay samples taken during summer produced fewer species than those for either spring or fall (28 vs 32 and 35). Winter collections in the Mullica River had more species than fall collections (15 vs 13) and more specimens per collection than either spring or fall (52.1 vs 33.2 and 44.5). This was due in part to the white perch, striped bass, and white catfish which overwintered in the deeper, more saline water near the mouth of the river.

Seasonal movements of the fishes into and within bay systems were evident (Tables 76 and 78). During the colder months, several species of the herring and cod families moved into the bays. Shore zone fishes such as the Atlantic silverside moved into the open bay. During the warmer months, adults of the bluefish, weakfish, and summer flounder used the bays for feeding. Young of these species and the black sea bass, scup, Atlantic menhaden, and tautog used the bays as a nursery. The silver perch and the bay anchovy spawned in the bays. Some subtropical and tropical species such as the jacks and pompanos entered the bays occasionally during the summer.

The Recurrent Group Analysis (Fager, 1957) was applied to the seasonal catch data. The only recurrent group found was that of the bay anchovy and winter flounder for spring. Both species were common and widespread during the spring.

In 1972, 52 species were collected in Little Egg Harbor, 51 in Great Bay, 46 in Brigantine, and 35 in the Mullica River (Table 77). The largest number of specimens per collection was taken in Brigantine zones (141.7+) followed by the Mullica River (67.6+), Little Egg Harbor (64.7+), and Great Bay (48.4+).

The Species Diversity Index indicated that Little Egg Harbor samples were the most diverse (1.31) and those in Brigantine were the least diverse (0.65). The Distance Measure showed the Brigantine and Great Bay communities to be similar (0.08) while the Little Egg Harbor community structure differed slightly from that of Great Bay (0.19) and Brigantine (0.22). The differences in species diversity and Distance Measure between areas can be largely attributed to differences in relative abundance of the bay anchovy.

The differences between the bays can be attributed to spatial differences in abundance of a few of the more numerous fishes (Tables 79-82). In Great Bay the white perch ranked second in abundance and the hogchoker was seventh. Few of these fishes were taken in the other bays. Relatively few specimens of the Atlantic silverside were taken in Great Bay.

In Little Egg Harbor the fourspine stickleback ranked seventh in abundance. It is often associated with eel grass which was absent in other bay systems. The blueback herring and Atlantic menhaden also ranked high in Little Egg Harbor due mainly to a few large collections of these fishes.

In Brigantine the bay anchovy predominated. Its number per collection was three times greater than in the other bays. Fishes may have concentrated in the deeper waterways where much of the sampling was done. Most of the open bay areas are very shallow and are not easily trawled.

In a comparison of habitats within a bay (Tables 83 to 91), the number of specimens per collection was greater in the inner bay and lower in the inlet. The inverse was true of the species diversity. In Little Egg Harbor the number of specimens per collection and the Species Diversity Index were 228.4 and 0.93 for the inner bay, 38.3 and 1.92 for mid bay, and 4.5 and

2.63 for the inlet. In Great Bay the number of specimens per collection declined toward the inlet. Species diversity was similar in the inner (0.86) and mid-bay (0.87) areas, and greatest in the inlet zones (1.82). In Brigantine the greatest number of specimens and the lowest diversity were found in the intracoastal waterway and the least number of specimens and highest diversity were found in the inlet.

Creek Trawling

A trawl program in Big and Little Sheepshead creeks was initiated in October, 1972, to determine the importance of tidal creeks in the bay-estuarine system. Five minute bottom hauls were made with a 16-ft semi-balloon trawl (Appendix Table 22).

Big Sheepshead Creek is broad and shallow whereas Little Sheepshead Creek is narrow and deep. Both are thorofares which connect Great Bay and Little Egg Harbor. A total of 18 species and 331+ specimens were taken in 19 collections (Table 92). Big Sheepshead Creek had more species and specimens (15 and 180) than Little Sheepshead Creek (12 and 151+).

Important species which utilize the creeks included the striped bass, white perch, spot, silver perch, scup, tautog, summer flounder, and winter flounder. During the fall greater numbers per collection of both silver perch and winter flounder were taken in the creeks than in the bays.

ICHTHYOPLANKTON

Thomas R. Tatham and Richard S. Stein

Introduction

The initial objective of the ichthyoplankton study was to identify and enumerate the fish eggs and larvae found in the vicinity of the Site, inlets and adjacent bay systems. Subsequently the program was expanded to examine the vertical distribution and early development of the eggs and larvae of ecologically and economically important species.

Materials and Methods

From February through December, 1972, ichthyoplankton collections were made in the vicinity of the Site; in Absecon, Brigantine, and Little Egg inlets; and in Little Egg Harbor, Great Bay-Mullica River estuary, and waterways behind Brigantine. All stations regularly sampled are described in Table 93.

In the vicinity of the Site, 15-minute surface collections were made with a 1.0-m plankton net (0.5-mm mesh) about every 2 weeks. The net was towed at 1.5 to 2.5 knots, 50 to 60 ft behind the boat. The volume of water sampled in summer and fall collections was determined by a digital flowmeter (General Oceanics, model 2030) placed in the mouth of the net. An estimate of the volume sampled in unmetered winter and spring collections was based on the summer and fall volumes ($\bar{x}$=613.2m^2, s^2=4317.6, s_d=208.4, n=60).

During summer and fall, 15-minute bottom and midwater collections were made in the vicinity of the Site at Ocean Stations 1, 3, and 4 (Table 93). Half meter (0.5-m) plankton nets (0.5-mm mesh) were attached to a line towing a 100-lb. depressor. Depressor and nets were retrieved with an electric windlass. As the nets were the non-closing type, some vertical contamination resulted primarily during retrieval. The contamination was estimated to be 10% or less of the total volume filtered on any one tow. Estimates of the volume sampled for unmetered summer and early fall collections were based on late fall volumes (midwater: $\bar{x}$=171.6m^3, s^2=229.6, s_d=15.1, n=9; bottom: $\bar{x}$=160.4m^3, s^2=493, s_d=22.2, n=8).

Ichthyoplankton was collected each week in Absecon Inlet by 1 hour sets of an unmetered 1.0-m plankton net suspended from the middle of the old Brigantine Bridge. Surface collections were made during the later stages of flood tide to monitor ichthyoplankton entering the bays.

Beginning in April 10-minute surface collections using a 0.5-m net were made weekly in Little Egg Inlet and once every two weeks in Brigantine Inlet. The net was towed 40 to 50 ft behind the boat at a speed of 2 to 4 knots. The estimated volume sampled for unmetered spring and early summer collections in the inlets was based on late summer and fall values ($\bar{x}$=167m^3, s^2=2226.5, s_d=47.2, n=30). A pooled estimate for both inlets was used since meter readings between inlets were not significantly different (t=0.3998, NS @ 0.01, 28 df).

Beginning in March, surface samples with a 0.5-m net were taken every other week in Little Egg Harbor, Great Bay-Mullica River estuary, and Brigantine waterways. The net was towed at 2 to 4 knots, 40 to 50 ft behind the boat. Most were 10-minute tows; however, the heavy detritus load in many areas and floating eel grass mats in Little Egg Harbor often filled the net and the tow had to be terminated prematurely. An estimate of the volume sampled for unmetered winter and spring collections was based on the volume sampled in summer and fall collections in all three bays ($\bar{x}$=169.1m^3, s^2=2167.9, s_d=46.6, n=111). No significant difference existed between average volume sampled in each bay.

All collections were preserved in the field in 5% formalin and, when necessary, stained with Rose Bengal to facilitate removal of ichthyoplankton. In the lab, eggs and larvae were removed, identified, and enumerated. When it was impractical to remove all the eggs or the larvae of one species, an estimate of their numbers was based on a subsample obtained with a Folsom

Sample Splitter. Fish eggs were stored in 5% formalin and larvae in 40% isopropanol.

Terminology used in the text follows Mansueti and Hardy (1967). Those fishes classified as smaller juveniles are included with the larvae in Appendix Tables 24 to 32 while larger juvenile and adult fishes are included in Appendix Table 33.

Many eggs and some larvae remain unidentified. This is due in part to inadequate descriptions in the literature. A number of eggs and larvae were identifiable to genus but not to species (Table 94). The category of unidentified fish includes those which are unidentifiable at this time or too mutilated for positive identification.

N/m^3 equals the average number of specimens/m^3 in water filtered. V equals the volume sampled only in the collections in which a given species appeared. N/V equals the average density of specimens only in samples in which the species appeared. Unless otherwise stated, all densities referred to in the text are N/m^3.

The nonparametric signed rank statistic (Tate and Clelland, 1957) was used to analyze the difference in monthly densities of total eggs and larvae collected at the ocean stations.

Results-Site

Fish Eggs

In the vicinity of the Site during winter (February-March), 15 surface collections yielded 1,285 eggs. The average density was $0.140/m^3$ (Table 95). Eggs collected during this period comprised only 0.3% of those taken in the vicinity of the Site in 1972. None have been identified.

During spring, 37 surface tows collected 221,309 eggs. The average density was $9.745/m^3$ (Table 95). These eggs represented 59.3% of those taken near the Site during 1972. The greatest number ($17.069/m^3$) was collected in May (Table 96). The majority of eggs collected in the spring was identified. Eggs of the tautog ($0.127/m^3$), bay anchovy ($0.086/m^3$), and Atlantic menhaden ($0.080/m^3$) were common.

During summer, 60 surface, midwater, and bottom collections in the vicinity of the Site yielded 144,898 eggs at an average density of $7.085/m^3$ (Table 95). Summer collections accounted for 38.8% of all eggs taken in the vicinity of the Site in 1972. Most of these were unidentified. Bay anchovy eggs ($1.756/m^3$) were common. The greatest number was collected in July at an average density of $4.747/m^3$ (Table 96). Eggs of striped anchovy ($0.052/m^3$), tautog ($0.216/m^3$), and searobins ($0.339/m^3$) were also collected (Table 95).

During fall, 77 surface, midwater, and bottom tows took 5503 eggs at an average density of $0.174/m^3$ (Table 95). These comprised 1.5% of the total collected at the Site in 1972. The majority of these were windowpane flounder eggs ($0.141/m^3$), most of which were taken in October.

In 1972, most (83.4%) fish eggs in the vicinity of the Site were unidentified. Those of bay anchovy (10.13%), tautog (1.95%), searobins (1.86%) and windowpane flounder (1.20%) comprised the major portion of identifiable fish eggs. Values for individual collections are in Appendix Tables 24-26.

Larval and Juvenile Fishes

During winter (February-March), 477 larval and juvenile fishes were collected in the vicinity of the Site in 15 surface tows (Tables 95 and 97).

The average winter density was $0.052/m^3$. These larvae represented 6.7% of all specimens collected there in 1972. American sand lance was the most abundant species ($0.044/m^3$) in winter.

During spring, 1756 specimens were collected in 37 surface tows; the density averaged $0.077/m^3$ (Tables 95 and 97). Specimens collected in spring comprised 24.6% of the total at the Site for 1972. American sand lance and winter flounder were taken in early spring while fourbeard rockling, Atlantic menhaden, Atlantic mackerel and northern pipefish were collected from mid-to-late spring (Tables 95 and 97).

In summer, 3134 larvae and juveniles were collected in the vicinity of the Site in 60 surface, midwater, and bottom tows (Table 95) at an average density of $0.153/m^3$. Summer collections accounted for 44% of the 1972 ocean catch. In early summer, anchovies, lined seahorse, and weakfish were the dominant species (Table 96). From mid-to-late summer, Atlantic menhaden, searobins, and butterfish were commonly collected (Tables 95 and 96).

During fall, 1759 larvae and juveniles were collected in 77 surface, midwater, and bottom collections. These specimens represented 24.7% of the 1972 ocean catch (Table 95). The average fall density was $0.056/m^3$. In early fall, Atlantic menhaden were common while from mid-to-late fall windowpane flounder and American sand lance were common (Tables 95 and 96). Values for individual collections are in Appendix Tables 24-26.

Summary

Most fish eggs (81%) taken in the vicinity of the Site were collected from May through July (Fig. 17). The majority (86.6%) of these eggs was unidentified. Those of the bay anchovy ($3.537/m^3$) and tautog ($1.180/m^3$)

accounted for 9.7% and 2.4%, respectively. The eggs of other species present during these months were Atlantic menhaden, mackerel, and cunner. Weakfish and fourbeard rockling eggs may have been included with the unidentified eggs. The peaks in egg densities in May and July may actually represent two separate spawning peaks or be the result of limited sampling during June.

April through July was the period of greatest abundance for larvae and juveniles in the ocean (Fig. 17). Atlantic menhaden, anchovies, fourbeard rockling, lined seahorse, northern pipefish, weakfish, American sand lance, and Atlantic mackerel were abundant. A second peak of larval abundance occurred in December due to the presence of American sand lance. Totals and densities for these fishes are given in Tables 95-99.

Results-Bays and Waterways

Fish Eggs

Some 229 surface collections in all bays and waterways sampled contained 649,709 eggs at an average density of 17.001/m^3 (Table 100). Monthly totals and densities for the individual bays are given in Tables 101, 102, and 103. The bay anchovy, Atlantic menhaden, tautog, red hake, searobins, scup, and cunner comprised 79.7% of the total. Some 20.2% of the eggs were unidentified.

Twenty-five winter samples (February-March) contained 270 eggs at an average density of 0.064/m^3 (Table 100). These eggs comprised 0.04% of the 1972 total and were all unidentified except for four winter flounder eggs.

During spring, 522,651 eggs were taken in 66 collections at an average density of 46.830/m^3. Eggs of the bay anchovy, Atlantic menhaden, tautog, red hake, scup, and cunner were common. The spring total included 23.3% unidentified eggs and comprised 80.4% of the 1972 total.

Summer samples contained 126,615 eggs from 71 collections with an average density of 10.594/m^3. The common identified eggs were those of the bay anchovy, searobins, striped anchovy, and tautog. The summer total included 7.2% unidentified eggs and comprised 19.5% of the 1972 total.

During fall, 173 eggs were taken in 67 collections at an average density of 0.016/m^3 (Table 100). Eggs of the windowpane flounder and spotted hake were common. The fall total included 69.4% unidentified eggs and comprised 0.03% of the 1972 total. Values for individual collections are given in Appendix Tables 27-29.

Larval and Juvenile Fishes

A total of 30,683 larval and juvenile fishes was collected in 229 surface collections in all bays and waterways at an average density of 0.803 specimens/m^3 (Table 100).

Winter samples (February-March) contained 547 specimens at an average density of 0.129/m^3 (Table 100). Larvae of the American sand lance and winter flounder were common. The winter total comprised 1.8% of the 1972 bay total.

During spring, 19,944 specimens were collected at an average density of 1.787/m^3 (Table 100). Silversides accounted for 88.3% of the catch in spring. Northern pipefish, winter flounder, anchovies, American sand lance, and threespine stickleback were also common. The spring total comprised 65.9% of the 1972 bay total.

Summer samples contained 3,984 specimens at an average density of 0.333/m^3 (Table 100). Silversides, anchovies, and northern pipefish were common. The summer total comprised 13.0% of the 1972 bay total.

During fall, 6,208 specimens were taken at an average density of $0.571/m^3$ (Table 100). American sand lance and Atlantic menhaden accounted for 97.7% of the fall catch. The fall total comprised 20.2% of the 1972 bay total. Values for individual collections are presented in Appendix Tables 27-29.

Summary

Monthly variations in the density of fish eggs were similar for each bay system during 1972 (Fig. 18). Large numbers of eggs were collected in Little Egg Harbor and the Brigantine waterways in May (10.4% of 1972 bay total); peak abundance occurred in all areas in June (68.5% of 1972 bay total). June collections from Little Egg Harbor yielded the greatest densities of most eggs. In August, only Little Egg Harbor continued to yield substantial numbers of eggs, primarily those of the bay anchovy and searobins. From September through November the numbers of eggs collected in all areas dropped to low levels.

Peak abundance of larval and juvenile fish occurred in June and December (Fig. 19). The spring peak (65% of 1972 bay total) occurred in all bays and was composed primarily of larval silversides. Silversides were most numerous in Brigantine waterways in June when they averaged $4.922/m^3$ (Table 101). The fall peak of abundance was composed almost exclusively of American sand lance larvae. These were taken in greatest numbers in Little Egg Harbor in December at an average density of $3.509/m^3$ (Table 102).

Larval and juvenile anchovies, silversides, threespine stickleback, northern pipefish, American sand lance, and winter flounder comprised 97.2% of the 1972 bay catch with less than 1% unidentified. Greatest densities of most of these species occurred in spring and summer collections (Table 104).

Total larval density was greatest in the spring in Brigantine waterways (predominately silversides) and in the fall in Little Egg Harbor(predominately American sand lance).

Results-Inlets

Fish Eggs

Densities for the three inlets were difficult to compare because of the lack of metered data from Absecon Inlet. The fishes were instead ranked by total numerical abundance within each inlet.

During winter, 15 surface tows collected 107 eggs at low densities (less than $0.1/m^3$). Eggs collected during the winter were unidentified and accounted for less than 0.1% of the 1972 inlet catch.

In spring, 28 surface collections yielded 282,903 eggs at average densities of $17.260/m^3$ (Brigantine Inlet) and $121.045/m^3$ (Little Egg Inlet). Eggs collected during spring accounted for 76.2% of the eggs collected in the inlets during 1972. Eggs of the bay anchovy and Atlantic menhaden were common.

During summer, 32 surface collections yielded 88,108 eggs at densities of $3.686/m^3$ (Little Egg Inlet) and $1.415/m^3$ (Brigantine Inlet). These comprised 23.7% of those eggs collected in the inlets in 1972. Eggs of the bay anchovy, striped anchovy, searobins, cunner, and tautog were common.

During fall, 32 collections yielded 218 eggs (less than 0.1% of 1972 inlet catch) at low densities. Windowpane flounder and spotted hake eggs were among those taken. Values for individual collections are presented in Appendix Tables 30-32.

Larval and Juvenile Fishes

In winter, 15 surface collections yielded 245 larvae and juveniles at average densities less than $0.03/m^3$. These specimens accounted for only 1.3% of all larvae and juveniles collected in the inlets in 1972. American eel, Atlantic menhaden, and American sand lance were common.

In spring, 28 surface tows contained 4,871 specimens at average densities of $0.329/m^3$ in Little Egg Inlet and $0.242/m^3$ in Brigantine Inlet; silversides, winter flounder, and American sand lance were common. Specimens collected in spring comprised 25.4% of all 1972 inlet specimens.

During summer, 32 surface collections yielded 9,554 larvae and juveniles at average densities of $0.092/m^3$ in Little Egg Inlet and $0.167/m^3$ in Brigantine Inlet; anchovies were common. Specimens taken in summer accounted for 49.8% of all inlet specimens.

During fall, 32 surface tows yielded 4,517 specimens at average densities of $0.244/m^3$ in Little Egg Inlet and $0.026/m^3$ in Brigantine Inlet. These specimens comprised 23.5% of the 1972 inlet catch. Atlantic menhaden and American sand lance were common. Values for individual collections are in Appendix Tables 30-32.

Summary

Eggs were most abundant in the inlets from May through July (Fig. 20) at which time they comprised 90.5% of all eggs taken in the inlets in 1972. Eggs of the bay anchovy (58.8% of 1972 inlet eggs) and Atlantic menhaden (0.7%) were the most common eggs identified during this period.

Most larvae and juveniles (67.6% of 1972 inlet specimens) were collected from May through July (Fig. 21). Specimens of silversides predominated in June (15.4% of 1972 inlet specimens) and anchovies in July (48.8%). A second peak of larval and juvenile abundance (12.8%), mostly specimens of the American sand lance, occurred in December. A small peak of Atlantic menhaden larvae and juveniles appeared in October.

Species Account

A literature review and accounts of the early life history stages of important species collected in the study area are presented.

Atlantic menhaden

The Atlantic menhaden, generally found in large schools, occurs along the coast from Nova Scotia to Florida. It undertakes north-south migrations, apparently in response to changing water temperature.

Atlantic menhaden spawn from late spring through summer in New England waters with a peak in June (Hildebrand, 1963). From Chesapeake Bay south, it spawns in late fall and early winter (Bigelow and Schroeder, 1953). There may also be a spring spawn in Chesapeake Bay, since menhaden eggs have been collected there in May and June as well as in October and November (Dovel, 1971). Many authors report that this species spawns at sea and that the distance from shore decreases in the northern part of its range (Bigelow and Schroeder, 1953; Hildebrand, 1963; Mansueti and Hardy, 1967). It may also spawn at the entrance of estuaries. Here the larvae are rapidly transported into the estuary via a subsurface, high salinity counter-current (Cronin and Mansueti, 1971).

Atlantic menhaden eggs are pelagic with an incubation time of about 48 hours at 22 C, 71.6 F (Mansueti and Hardy, 1967). In 1972, 17,866 menhaden eggs were collected in the study area. Most of these (73.4%) were taken in the bays, primarily in Little Egg Harbor (zone 2020) and Brigantine waterways (zones 2530 and 2550). Only two menhaden eggs were collected in Great Bay. The numbers taken in the inlets and ocean were almost equal (13.8% and 12.8%, of the yearly total). Peak abundance occurred in May and spawning probably took place both in the bays and ocean. A second, smaller spawn was indicated by the presence of eggs in the ocean in September and October. Totals and densities of eggs and larvae are given in Tables 95-107.

Shortly after hatching, menhaden larvae move shoreward to enter estuarine nursery grounds (Mansueti and Hardy, 1967). Of the total 3,358 larval and juvenile menhaden taken, 65.7% were collected in the inlets, 19.9% in the ocean, and 14.4% in the bays. Larvae were most abundant in all areas in October. Although adult menhaden left the study area as water temperature dropped, juvenile specimens were collected by trawl both in the bays and ocean through the fall and winter. The lower lethal temperature for larval menhaden (17 to 34 mm TL) has been reported as 3.4 to 5.2 C (38.1 to 41.4 F) depending on acclimation temperature and time (Brett, 1970).

Bay anchovy

The bay anchovy occurs in inshore waters from the Gulf of Maine to Yucatan, Mexico. This euryhaline species has been reported from a large variety of habitats and is abundant along the New Jersey coast (Hildebrand, 1963; Mansueti and Hardy, 1967).

The bay anchovy apparently spawns over most of its range. Hildebrand (1963) reported distinct populations for separate coastal areas with migration limited to an inshore-offshore movement. Spawning occurs primarily in protected inshore waters from early spring to late summer with peak activity in July and early August. Bay anchovy eggs have been reported from waters having a temperature range of 12.2 to 26.7 C (54.0 to 80.1 F) and a salinity range of 1 to 27.9 ppt. In Chesapeake Bay, eggs were most abundant in salinities of 13 to 15 ppt (Dovel, 1971). Small numbers of bay anchovy eggs have been collected along the New Jersey coast at Corson's Inlet (McDermott, 1971) and in the Sandy Hook estuary (Croker, 1965).

Its pelagic eggs hatch in about 24 hours at an average temperature of about 26.7 C (80.1 F). Although larvae have been collected in both salt and brackish water, in Chesapeake Bay they utilized the low salinity (3 to 7 ppt), estuarine area as a nursery and were most abundant at temperatures between 22.8 and 26.7 C, 73.0 to 80.1 F (Dovel, 1971).

Bay anchovy eggs, larvae, juveniles, and adults were collected throughout the study area during 1972. Examination of data from plankton and trawl net collections (Table 108) suggested that adult anchovies moved inshore in April and May and entered the bays to spawn. Spawning began in May, peaked in June and continued at least through August. The large percentage of eggs collected in the bays indicated that most, if not all, spawning occurred there. The wide distribution of eggs precluded designation of any particular areas as spawning sites. Plankton and trawl net collections of larvae and juveniles indicated that the inner bays and lower portion of the Mullica River were utilized as nursery areas. Juvenile and adult anchovies began to move out of the bays into inshore ocean waters in September and October, followed by their virtual disappearance from the area by mid-November when water temperatures dropped below 10 C (50 F).

The bay anchovy was reported as the most abundant fish in Chesapeake Bay (Hildebrand and Schroeder, 1928; McHugh, 1967) and its eggs were the most abundant fish eggs in Long Island Sound (Wheatland, 1956).

Bay anchovy eggs comprised 93.4% of the identified eggs collected in the study area during 1972. In bay and ocean collections it ranked first numerically among identified eggs; third in the bays and second in the ocean among identified larvae; and second among juveniles and adults from all areas. They were most numerous in Little Egg Harbor (54.819/m^3, N/V), followed by Brigantine waters (37.925/m^3, N/V), Great Bay (24.366/m^3, N/V) and the vicinity of the Site (3.601/m^3, N/V). The greatest numbers of anchovy larvae were collected in bottom tows in the vicinity of the Site. The lower numbers collected in the bays probably resulted from the exclusive use of surface tows. Anchovy larvae migrate out of surface waters after they reach about 12 mm total length (Mansueti and Hardy, 1967). Totals and densities are given in Tables 95-107.

Fourbeard rockling

The fourbeard rockling is found in the coastal waters from the Gulf of St. Lawrence to Long Island Sound. It occurs in deeper waters to North Carolina. They are considered year-round residents in the Gulf of Maine with the greatest concentration at depths between 150 and 180 ft (Bigelow and Schroeder, 1953).

The fourbeard rockling comprised a substantial portion of the larvae and juveniles collected during the spring in the vicinity of the Site. Their pelagic eggs are spawned from spring to early autumn (Bigelow and Schroeder, 1953; Colton, Marak, and Miller, unpublished). Breder and Rosen (1966) reported that fourbeard rockling eggs hatch in 17.9 days at 5 C(41 F) and 3.2 days at 19 C (66.2 F). Battle (1930) reported a normal development between 13 and 19 C (55.4-66.2 F).

Data from the vicinity of the Site in 1973 indicated that fourbeard rockling eggs occurred as early as March. Larval fourbeard rockling appeared in 1972 collections from early May through July. The early larvae and juveniles are planktonic for 2 to 3 months before descending to the bottom at a size of 40 to 45 mm (Bigelow and Schroeder, 1953). Numerous specimens from 20 to 30 mm and a 38 mm specimen were collected in June. The general absence of the 30-40 mm size group may be due to net avoidance by larger juveniles or descent of the juveniles to the bottom. Trawl collections in the vicinity of the Site in late June caught specimens 32-49 mm in length.

June collections contained the highest densities of larvae and juveniles ($0.044/m^3$). The majority of the specimens was taken at a distance greater than 2 miles from shore. Fourbeard rockling appeared infrequently in bay collections although a large number of juveniles was collected in one seine collection. Larval and juvenile fishes were more common in inlet collections than in bay collections. Totals and densities are given in Tables 95-107.

Bigelow and Schroeder (1953) found that the inshore region (0-10 miles off the coast) of Massachusetts Bay was an important nursery ground for rockling spawned in the Gulf of Maine. Croker (1965) indicated that the nearshore ocean (0.5 miles off Sandy Hook, N. J.) was a nursery area for young rockling.

Silversides

Two closely-related species of silversides, the Atlantic silverside and the tidewater silverside, commonly occur along the Atlantic coast. The former ranges from Nova Scotia to northern Florida; the latter from Cape Cod to South Carolina. A third species, the rough silverside, ranges from New York to Mexico. Only three adults of the rough silverside were collected in the study by seine in 1972.

Silversides spawn from early spring to late summer in shallow water. The demersal eggs have gelatinous threads which become attached to aquatic vegetation. The adhesive eggs were virtually inaccessible to standard plankton gear and few were collected during 1972. Hildebrand and Schroeder (1928) reported that incubation time for Atlantic silverside eggs was 16 days at 4.4 to 15.6 C (39.9 to 60.1 F) and for tidewater silverside eggs it was 8 to 10 days at 25.6 to 27.8 C (78.1 to 82.0 F).

The larvae of these two fishes can only be readily differentiated by the difference in their hatching size; the Atlantic silverside is about 5.0 mm total length (TL) and the tidewater silverside about 3.5 mm TL at hatching (Hildebrand, 1922). The great majority of silverside larvae collected was Atlantic silverside since, of 544 yolk-sac and early larvae measured, only 2.6% were between 3.4 and 4.0 TL. Another indication of the relative abundance of the two species was that the tidewater silverside comprised only 2.4% of the total 154,029+ juvenile and adult silversides collected in the study area by seine in 1972. The tidewater silverside was more abundant in low salinity water than was the Atlantic silverside (Tables 13-16).

Larval silversides were collected in each bay system from mid-May to early August with peak abundance in June. They ranked first in abundance and comprised 64.6% of all larvae and juveniles collected in the three bays. Silverside larvae comprised 88.1% of all larvae collected in Brigantine waterways, 45.9% in Little Egg Harbor, and 52.9% in Great Bay in 1972. Their densities, in decreasing order, were 2.911/m^3 (N/V) in Brigantine waterways, 1.282/m^3 (N/V) in Little Egg Harbor, and 1.143/m^3 (N/V) in Great Bay and the Mullica River. In the Brigantine waterways silverside larvae were abundant in all zones. In Little Egg Harbor, almost three-fourths of the catch came from mid- and inner bay zones (2040 and 2080). Almost two-thirds of the catch from Great Bay and the Mullica River was taken in the inner bay zone 1070. Totals and densities are given in Tables 95-107.

Northern pipefish

The northern pipefish is common in salt and brackish waters along the Atlantic coast from Nova Scotia to South Carolina. It is usually found associated with eel grass or other aquatic vegetation and is believed to be non-migratory except for its movement to deeper water during winter.

The northern pipefish spawns from March to August in New England waters (Bigelow and Schroeder, 1953) and from April to October in Chesapeake Bay

(Hildebrand and Schroeder, 1928). The female deposits her eggs in a brood pouch located on the male's ventral surface. Incubation time is about 10 days. After hatching the larvae are retained in the pouch until their yolk sacs are absorbed. They leave the pouch at a length of about 10 mm (Bigelow and Schroeder, 1953).

A total of 1,212 larval and juvenile pipefish was collected in 1972. Peak abundance occurred in June when 63.9% of the total were collected. Spawning apparently took place primarily within the bays since the catch there accounted for 77.9% of the total whereas only 11.1% were taken in the vicinity of the Site. The densities of the catch from each bay showed little differences (Great Bay 0.076/m^3, N/V; Little Egg Harbor 0.072, N/V; Brigantine waterways 0.051, N/V). Monthly and seasonal totals and densities are given in Tables 95-107. The zones of greatest concentration were 1050 and 1070 in Great Bay, 2040 in Little Egg Harbor, and 2530 and 2600 in Brigantine waterways.

Lined seahorse

The lined seahorse ranges from Cape Cod to the Carolinas and is usually associated with vegetation. The eggs are spawned in early April (Roule, 1928) and following internal fertilization are transfered from the female's pouch to the male's pouch. The young are shed from the male's pouch during the summer in New Jersey (Croker, 1965) and Chesapeake Bay (Dovel, 1971). Males usually incubate broods of 150 (Bigelow and Schroeder, 1953) to several hundred (Breder, 1940). Nine hundred twelve larval seahorses were removed from the pouch of a male on 3 August 1972. Dovel (1971) collected juvenile lined seahorses in water of 23-25 C (73.4-77 F) and 13-21 ppt.

The majority (98%) of juvenile lined seahorse collected in the ocean was taken in July and August. Most juveniles (75.9%) were taken in surface collections during July and were collected in approximately equal densities at all stations except the Site where their density was 2.5-8 times greater.

The majority (95.2%) of juvenile lined seahorse collected in the bays was taken in June (51.8%), July (21.7%), and August (21.7%). Juvenile seahorses were taken throughout the bays, although most were collected in Little Egg Harbor. Total numbers and densities were lower in the bays than in the ocean (Tables 95-107).

Weakfish

Although no weakfish eggs were identified, some spawning undoubtedly occurred in the vicinity of the Site and possibly in the bays. Weakfish are reported to spawn from mid-May to late July (Welsh and Breder, 1923; Daiber, 1957; Harmic, 1958; Thomas, 1971). Daiber (1957), Harmic (1958), and Thomas (1971) reported at least two spawns in Delaware Bay; the first was in June and the second occurred in July. Hildebrand and Cable (1934) reported the spawning season to be independent of latitude. Spawning of larger fish may precede the spawning of smaller adults (Hildebrand and Cable, 1934; Daiber, 1957).

At 20-21.1 C (68-70 F), weakfish eggs have been reported to hatch in 12 to 40 hours (Hildebrand and Schroeder, 1928; Harmic, 1958; Bigelow and Schroeder, 1953). Harmic (1958) collected eggs at 17 to 26.1 C (62.6-79 F) and 12.1 to 31.3 ppt in Delaware Bay. Bigelow and Schroeder (1953) collected eggs at 15.6 to 21.1 C (60-70 F) and 28 to 30.9 ppt in the Gulf of Maine.

The weakfish is reported to spawn in bays (Daiber, 1957; Welsh and Breder, 1923), near the mouths of bays (Massmann, Whitcomb, and Pacheco, 1958) and in both of the above areas (Bigelow and Schroeder, 1953; Harmic, 1958). Hildebrand and Cable (1934) believed weakfish left the bays near Beaufort, North Carolina to spawn at sea. Harmic (1958) indicated some spawning offshore of Delaware Bay.

Following hatching, the larvae sink to the bottom and may move up into estuaries in subsurface currents (Thomas, 1971). Thomas (1971) found that young concentrated in low salinity areas of Delaware Bay. He reported that the low salinity estuary was an important nursery area from June through August. He found that larvae decreased in number in September due to emigration, predation and natural mortality.

Because of the lack of bottom samples during June in the vicinity of the Site, an early spawn may have been missed. Trawl collections, however, gave no indication of an early spawn. The majority of the larvae collected was taken in bottom collections in the ocean during mid-July (Table 99). The bottom densities and sizes (2.2-4.3 mm TL) of larval weakfish were approximately equal at all ocean stations with the exception of the ridge where bottom density was lower. Larval weakfish were collected in bay surface collections only in the Brigantine waterways. These stations were at shallow depths where turbulence negated stratification. Totals and densities for the study area are given in Tables 95-107.

American sand lance

The American sand lance occurs along the Atlantic coast from Labrador to Cape Hatteras and is common along the New Jersey coast (Bigelow and Schroeder, 1953). Larval sand lances have been reported as abundant in ocean waters adjacent to Chesapeake Bay, although rare within the Bay (Norcross, Massmann, and Joseph, 1961). Wheatland (1956) collected larval sand lances in Long Island Sound, N. Y.

Spawning activity has never been observed, but the occurrence of larval sand lances indicates that it takes place over the inner half of the continental shelf from fall to early spring (Norcross, Massmann, and Joseph, 1961). In Long Island Sound, spawning was reported to begin when bottom water temperature dropped to 9 C (48 F) or lower. Peak spawning was from January to March (Wheatland, 1956; Richards, 1959).

American sand lance eggs have not been described. None were collected in the study area in 1972 using standard plankton nets. However, eggs believed to be of this species were taken in a ponar grab from the top of the Ridge during late November at a depth of 25 ft. They were attached to sand grains. Fertilized eggs were obtained from ripe adult sand lances taken by trawl in the intracoastal waterway in Little Egg Harbor on 21 December 1972. Eggs of the Pacific sand lance, Ammodytes hexapterus Pallas, were reported from two sites on the north shore of Long Island, N. Y. from late November to late March (Williams, Richards, and Farnsworth, 1964). The description of these eggs is similar to that of the eggs obtained from ripe adult American sand lance. Eggs of the European sand lance, Ammodytes tobianus, were reported as demersal, adhesive, and attached to sand grains. Their incubation time was from 20 to 24 days at a water temperature of about 7 C, 44.6 F (Breder and Rosen, 1966).

Previous studies have indicated the presence of sand lance larvae in waters with salinities as low as 1.8 ppt (Chamberlin, cited in Norcross et al., 1961) and as high as 30 ppt (Norcross et al., 1961).

During 1972, sand lance larvae were collected in the bays at salinities from 19.5 ppt to 32 ppt. However, in February, 1973, a few larvae were collected in the lower portion of the Mullica River at a salinity of 12 ppt.

A total of 8.776 larval and juvenile sand lances were collected in 1972. Peak abundance occurred during December when 78.8% of the total were collected. For 1972, 70.3% were taken in the bays, primarily Great Bay and Little Egg Harbor. Totals and densities are given in Tables 95-107.

A large number of larvae was collected in proximity to Little Egg Inlet. Ripe adults were taken within Little Egg Harbor. Sand bottomed areas in the inlets and bays as well as the ocean may serve as spawning areas.

Atlantic mackerel

The Atlantic mackerel ranges from Cape Hatteras to the American coast of Labrador (Hildebrand and Schroeder, 1928). It migrates north along the New Jersey coast in April and May and south in November. Spawning occurs in mid-April in southern regions, in May off New Jersey, and in June off southern Massachusetts. The most extensive spawning occurs from the Chesapeake capes to Massachusetts Bay (Sette, 1943). The Atlantic mackerel generally spawns at least a few miles from shore although the spawning grounds vary from year to year (Bigelow and Schroeder, 1953).

Perlmutter (1939) collected eggs off Montauk Point, Long Island in June at temperatures of 13.3 to 14.4 C (56-58 F). Wheatland (1956) collected eggs in Long Island Sound from mid-May to June at temperatures of 13.8-17.6 C (57-63.5 F) and salinities of 18.2-24.4 ppt. Hildebrand and Schroeder (1928) reported spawning from 7.8-16.1 C (46-61 F). Worley (1933) found that mackerel embryos collected at 12-18 C (53.6-64.4 F) and tested at 34 ppt salinity had an upper lethal temperature of 21 C (69.8 F) and a lower lethal temperature of 11 C (51.8 F). The optimum temperature was 15-16 C (59-60.8 F). Bigelow and Schroeder (1953) reported that Worley (1933) found the following incubation times: 210 hours at 10 C (50 F), 150 hours at 12.2 C (54 F), 115-96 hours at 13.9-16.1 C (57-61 F), 70 hours at 17.8-18.3 C (64-65 F) and 50 hours at 21.1 C (70 F).

Although no eggs were identified from samples, some spawning undoubtedly occurred in the vicinity of the Site. Larvae were collected in late May at temperatures of 14-17.5 C (57.2-63.5 F) and salinities of 26-29 ppt. Totals and densities are given in Tables 95-107.

Searobins

The northern searobin and striped searobin are inshore fishes which occur commonly from South Carolina to Cape Cod (Leim and Scott, 1966). Searobins move offshore with colder winter temperatures and return inshore during the warmer months. Generally, both species spawn from late spring to early August although the northern searobin may spawn into early September (Perlmutter, 1939; Wheatland, 1956; Marshall, 1946; Bigelow and Schroeder, 1953). Hildebrand and Schroeder (1928) reported that Welsh and Breder obtained ripe northern searobins off Atlantic City, New Jersey from 19 to 25 August 1920. Croker (1965) collected searobin eggs from May to June off Sandy Hook, New Jersey. McDermott (1971) collected searobin larvae from June through September in several New Jersey inlets.

Northern searobin eggs kept at 22 C (71.6 F) hatched in 60 hours (Kuntz and Radcliffe, 1917). Marshall (1946) reported that Breder hatched eggs maintained at 20-21.1 C (68-70 F) in 89 hours.

Searobin eggs were collected in the present study from July through September. Eggs were more abundant in August than in September or July. The majority of eggs were collected in the vicinity of the Site, primarily 2 or more nautical miles off the beach. This distribution approximates the summer distribution of adults and indicates that most of the eggs were probably spawned in the immediate vicinity. In the bays, searobin eggs had a patchy distribution. These eggs may have resulted from bay spawning or, more likely, from eggs carried into the bays.

All searobin larvae (probably P. carolinus) were collected in the ocean in September and October with the majority occurring during late September. Most searobin larvae were taken 2 or more nautical miles from shore. Northern searobin larvae were more common in collections from midwater and the bottom than at the surface. Totals and densities are given in Tables 95-107.

Windowpane flounder

The windowpane flounder is a year-round resident in the study area. It occurs most commonly from the tide mark to 150 ft (Bigelow and Schroeder, 1953). It ranges from the Gulf of St. Lawrence to South Carolina but is most abundant southwest of Cape Cod (Bigelow and Schroeder, 1953).

Perlmutter (1939) reported that windowpane flounder spawned in Long Island waters from May to August. Nichols and Breder (1927) suggested that spawning off Sandy Hook, New Jersey commenced as early as March or April, whereas Croker (1965) collected eggs in May and June. Wheatland (1956) found a spring spawn from April to July and a fall spawn from mid-September to early November off Long Island. Hildebrand and Schroeder (1928) found fish with well developed gonads in late September. McDermott's (1971) data indicated a split spawning season for the New Jersey coast.

Bigelow and Schroeder (1953) found that artificially fertilized eggs hatched successfully from 10 to 21.1 C (50-70 F) and that their incubation required 8 days at 10.6-13.3 C (51-56 F). Wheatland (1956) found spawning in the spring from 6.5 to 22.2 C (43.5-72 F) and in the fall from 21.5 to 13.5 C (70.7-56.3 F). Salinities ranged from 18.1 to 30.0 ppt.

The larvae remain pelagic until they are approximately 10 mm in size. At this size, metamorphosis is complete and the fish becomes demersal (Bigelow and Schroeder, 1953).

Although no eggs and few larvae were identified in the spring ichthyoplankton from the study area, spawning must have commenced in April since small (10-20 mm) windowpane flounder were taken in the ocean by trawl in June. The presence of larvae in late July samples indicated that the 1972 spawn lasted into June.

A second spawning period in the fall was noted in the study area. The majority of eggs was collected in October although some spawning continued into November. Eggs were collected in water from 17.0 to 9.5 C (62.6-49.1 F) and salinities of 26-31.5 ppt. Although some spawning probably occurred in the vicinity of the Site, the majority of the eggs were apparently spawned seaward of the Ridge and offshore. A decreasing density gradient of eggs existed from seaward of the Ridge to the inlet (Table 109). Size classes of larval windowpane flounder were distributed by depth. Larvae taken at the surface ($\bar{x}$=3.2 mm TL, s_d=0.8, n=27) were significantly smaller than those collected at midwater ($\bar{x}$=4.2 mm TL, s_d=1.3, n=55). Both surface and midwater larvae were significantly smaller than bottom larvae ($\bar{x}$=7.3 mm TL, s_d=3.5, n=13). The larger bottom larvae indicated the settling of metamorphosing larvae.

Winter flounder

The winter flounder is a common commercially important species found along the Atlantic coast from Labrador to Chesapeake Bay. It has been recorded as far south as Georgia (Bigelow and Schroeder, 1953). This species undertakes an inshore-offshore migration which is apparently controlled by water temperature. South of Long Island, New York, adult winter flounder move into the shallow inshore ocean waters and bays in the fall as water temperatures drop to 15 C (59 F) or lower. It spawns during the winter and spring and moves offshore in the summer when water temperatures rise above 15 C (Bigelow and Schroeder, 1953; McCracken, 1963; Leim and Scott, 1966). The preferred temperature range of adult winter flounder is between 12 and 15 C, 53.6 to 59.0 F (McCracken, 1963). Upper and lower lethal temperature limits of juveniles are 22.0 to 29.1 C (71.6 to 84.4 F) and 1.0 to 6.0 C (33.8 to 42.8 F), respectively, depending on acclimation temperature and time (Brett, 1970).

Peak spawning is in February and March. It takes place primarily in the shallow, sandy bottomed bays, although some spawning may occur in inshore ocean waters (Hildebrand and Schroeder, 1928; Bigelow and Schroeder, 1953; Leim and Scott, 1966). Although very few ripe flounder were taken in the bays, concentrations of larvae seemed to indicate that most of the spawning occurred there.

Winter flounder eggs are demersal and not susceptible to collection by standard plankton gear. Only four eggs were taken during 1972. Their incubation time has been reported as 15 to 18 days at 2.8 to 3.3 C (37 to 38 F) by Bigelow and Schroeder (1953) and 18 to 26 days at 4.4 to 15.6 C (40 to 60 F) by Leim and Scott (1966). Eggs were fertilized from ripe adults taken in the ocean on 28 February 1972. Incubation time of these eggs was 7 to 10 days at 3 to 12 C (37.4 to 53.6 F).

In 1972, 1,633 larval winter flounder were collected in the bays, inlets, and in the vicinity of the Site. The percentage of the total yearly catch in these areas was 41.5%, 46.6% and 11.9% respectively. Larvae were most abundant in April, which indicated a spawning peak in March. They were most abundant in Little Egg Harbor (0.165/m^3, N/V), followed by Great Bay (0.074/m^3, N/V), Brigantine waterways ($0.042/m^3$, N/V), and the vicinity of the Site ($0.019/m^3$, N/V). Large numbers of larvae (667) were taken in Absecon Inlet in collections taken during the latter part of flood tide. The zones of greatest concentration within the bays were 2040 in Little Egg Harbor, 1080 in Great Bay, and 2530 in Brigantine waterways. The catch in Little Egg Harbor accounted for 57.6% of the winter flounder larvae taken in the bays. Daytime surface catches of winter flounder larvae represented conservative estimates of their abundance, since they have been reported to concentrate close to the bottom in Chesapeake Bay (Dovel, 1971) and were about nine times more abundant in night surface catches in the Sandy Hook estuary (Croker, 1965). Totals and densities are given in Tables 95-107.

Only two winter flounder larvae were collected after May, 1972. By June, large numbers of young (25-70 mm) were taken in bay seine collections. They occurred in the shore zone of the bays throughout the summer, indicating the importance of these areas, especially Little Egg Harbor, as nursery grounds for the species.

Discussion

Of the three areas sampled, the ocean in the vicinity of the Site and the bays are of greatest interest. The inlets do not possess a unique ichthyoplankton fauna but serve as a passageway between bays and ocean.

In the ocean, the monthly densities (N/m^3) of fish eggs (all species combined) was significantly greater (at the 0.01 level) seaward of the Ridge and at the Ridge than landward of the Site and at the inlet. The monthly densities of total fish eggs at the Site was not significantly different than at any other ocean station. The data for specific eggs were insufficient for meaningful statistical analysis.

During the summer, greater densities of eggs were taken in surface samples than in midwater or bottom collections. This difference was most pronounced in July when egg densities were highest. During the fall, the densities of eggs in surface, midwater, and bottom collections were approximately equal (Table 110).

For 1972, the density of fish eggs was 3.8 times greater in the bays ($17.001/m^3$) than in the vicinity of the Site ($4.445/m^3$). During the spring peak of egg production, the density in the bays ($46.830/m^3$) was 4.8 times greater than that in the vicinity of the Site ($9.754/m^3$). The spawning times of various species are shown in Figure 22. Eggs of the bay anchovy comprised the majority (61%) of all eggs collected in 1972. These eggs were more common in the bays than ocean. Atlantic menhaden spawn at the mouth of estuaries (Cronin and Mansueti, 1971) and this may account for the higher concentration of eggs in the bays ($0.343/m^3$) than in the vicinity of the Site ($0.027/m^3$). Tautog (0.8% of all 1972 eggs) and cunner (0.2%) appeared to spawn equally in the bays ($0.089/m^3$) and in the vicinity of the Site ($0.087/m^3$) from May through July. Windowpane flounder and searobins spawned primarily offshore and in the vicinity of the Site. Their eggs were more common in the vicinity of the Site than in the bays. Several other important ocean spawners whose eggs were not identified in the 1972 ichthyoplankton collections are Atlantic mackerel, weakfish, and fourbeard rockling.

Our current sampling technique is selective for pelagic eggs. Demersal eggs are difficult to sample in water over a few feet deep and it is therefore impossible to enumerate them. Important demersal spawners in the area are American sand lance, winter flounder, and sculpins. Benthic sampling gear has collected American sand lance eggs on the Ridge near the Site and longhorn sculpin eggs in Little Egg Inlet.

The bays were also found to have higher densities of larvae and juveniles than the ocean in the vicinity of the Site. The density of larvae and juveniles was 9.5 times greater in the bays ($0.803/m^3$) than in the vicinity of the Site ($0.085/m^3$) during 1972. During the spring peak of abundance, the density in the bays ($1.787/m^3$) was 23.4 times greater than in the vicinity of the Site ($0.077/m^3$). Months when important larvae were present in the study area are shown in Figure 22.

In the ocean, the monthly densities of total larvae and juveniles were not significantly different seaward of the Ridge, at the Site, and landward of the Site. Insufficient data prevented statistical analysis of the ocean distribution of specific larvae.

The most abundant larval and juvenile fish collected in 1972 was the Atlantic silverside (40% of all larvae and juveniles for 1972). The bay anchovy was the second most abundant larval and juvenile fish collected (23%). The larvae were equally distributed between the bays ($0.088/m^3$, summer 1972) and the ocean in the vicinity of the Site ($0.113/m^3$, summer 1972). American sand lance was more common in the bays ($0.519/m^3$) than in the vicinity of the Site ($0.040/m^3$). The Atlantic menhaden (5.9%) was found in approximately equal densities in the vicinity of the Site ($0.008/m^3$) and in the bays ($0.013/m^3$). The winter flounder (2.7%) was taken in higher densities in the bays ($0.046/m^3$) than in the vicinity of the Site ($0.007/m^3$).

Several fishes did not appear in our samples in the numbers expected. Our estimate of weakfish larvae density was probably low. The larvae are bottom dwellers and few bottom samples were taken during the early part of their spawning season. The numbers of juveniles collected by seine and trawl indicated a significant weakfish spawn in the "nearshore areas". Silver perch did not appear in our collections although seine and trawl data indicated a sizable spawn in the area. Gobies did not appear in the numbers expected from previous reports for Great Bay (McClain, 1972) and other New Jersey estuaries (McDermott, 1971). Both silver perch and goby larvae may have been missed by the lack of samples from their preferred spawning habitat. Our low estimates of anadromous fish larvae (herring and white perch) resulted from few samples in tidal fresh waters of the upper Mullica River.

The colonization and successful spawning on and around the plant breakwater will likely lead to an increase of the eggs and larvae of certain species in the vicinity of the Site. Goosefish, lined seahorse, pipefish, tautog, cunner, longhorn sculpin, and northern puffer are fishes which have been observed on New Jersey artificial reefs (Steimle, personal communications) and which have been collected in the Site ichthyoplankton. Black sea bass and scup have also been reported on New Jersey artificial reefs (Thomas et al., 1971) but their larvae have not been collected to date near the Site.

The greatest numbers of eggs and larvae collected during 1972 from all areas combined were those of important forage species.

Data from 1972 represent a conservative estimate of the utilization of the area for spawning and as a nursery. Limitations of the sampling program included the lack of night and bottom collections, inaccessibility of demersal fish eggs to the sampling gear, possible net avoidance by larger larvae, and limited sampling for eggs and larvae of anadromous or shore zone fishes. Expansion of the sampling program will eliminate many of these limitations.

SPORT FISHERIES

H. Keith Hoff

Sport fishing occurs throughout the year in the vicinity of Little Egg Inlet. Boat fishing is common and at times intensive. Bank fishing occurs on the Mullica River, in the vicinity of Graveling Point on Great Bay, and on the creeks along Great Bay Boulevard.

Younger and Zamos (1955) stressed the importance of New Jersey's marine sport fisheries. They reported that the sport catch of fishes such as striped bass, bluefish, weakfish, summer flounder, and scup often equaled the commercial landings.

A study of the Mullica River-Great Bay estuary in 1969 by Hamer (1972) demonstrated its importance as a major recreational area. Fishing comprised 70% of all recreational activities and approximately one million fish were taken annually. The percentage of the fish catch during three months in the summer was as follows: July 38%, August 14%, and September 11%. The northern puffer made up more than half of the total catch of boat fishermen. Other important species were white perch, winter flounder, bluefish, and striped bass in that order. The northern puffer has been scarce in the last several years.

Most boat fishing information reported herein was obtained from personnel associated with two charter boats, the Valiant II and Melody II, berthed in Oyster Creek on Great Bay. Additional information was collected from private boats and other charter boats operating out of Oyster Creek (Table 111).

The catch of pier fishermen was recorded at Sea Horse Pier in Brigantine. Data presented include number of fishermen, hours fished, and total number of each sport fish taken. Sport fishes taken with hook and line by Ichthyological Associates' staff biologists were measured and scales were taken for age and growth analysis.

The Valiant II fishes approximately 200 days a year. During the period from July to November, the greatest number of fish was caught in July (Table 112). On 27 fishing days in July, 3,322 fish were taken. The catch consisted of 71% weakfish, 17% summer flounder, and 12% bluefish. The average catch was 17 fish per man for 74 fishing days in the period from July to November.

The species composition of the catch of the Melody II was similar to that of the Valiant II. The greatest number of fish (1,497) was caught during 16 days of fishing in August (Table 113). The August catch consisted of 58% weakfish, 33% summer flounder, and 8% bluefish. The Melody II fishes approximately 150 days a year. During 39 days from August to November,1972, the average catch was 11 fish per man.

The catch from Sea Horse Pier was representative of those fishes likely to be taken in and just beyond the surf zone (Table 114). The greatest number of fish was taken in August, when 3,259 fish were caught in 24 days. During August, the total catch consisted of 50% weakfish, 32% spot, and 13% silver perch. Bluefish caught from the Pier were predominately juveniles (snapper blues). During 78 fishing days at Sea Horse Pier, the average catch was two fish per man.

A comparison of the catches between Sea Horse Pier and the two charter boats, Valiant II and Melody II showed differences between surf and boat fishing.

The catch from Sea Horse Pier from August to October included the following: 44% weakfish, 23% spot, 21% bluefish (snapper blues), and 8% silver perch (Table 114). The combined catch from two charter boats was as follows: 63% weakfish, 14% summer flounder, 11% bluefish, and 3% black sea bass (Table 115).

Seasonally, the dominant sport fishes in the immediate area of the Site include Atlantic mackerel (spring); striped bass (spring and fall); weakfish (summer and fall); bluefish (summer and fall); and summer flounder (summer). During the summer and fall most charter boats from Oyster Creek fish the ocean in the vicinity of Little Egg Inlet. Spring sport fishing from charter and private boats for winter flounder and striped bass occurs in the bays and waterways. During spring, charter and private boats often fished for Atlantic mackerel 3 to 4 miles east of the Site. At times as many as 200 boats have been seen in the vicinity of the Site, particularly during summer.

Many of the other sport fishes recorded were taken while fishing for the major sport fishes mentioned above. However, species such as the tautog, northern kingfish, black sea bass, and a few other were sought regularly along the creeks, ocean surf, near jetties and pilings, and over wrecks in the ocean.

COMMERCIAL FISHERIES

H. Keith Hoff

New Jersey presently supports several major and minor commercial fisheries (Thomas et al., 1972). Commercial fishermen who worked in the vicinity of the Site use otter trawls, pots, gill nets, and to a lesser degree, purse seines, fyke nets, and long lines. Data were obtained from catches taken by the first three methods at four commercial fisheries docks. The fork length was measured for specimens from one box, or about 100 lb. of each species. Scales for age and growth studies were taken from 10 fish of each species.

The otter trawl fishery is basically for food fish. In New Jersey, commercial boats are based at Point Pleasant, Atlantic City, and Cape May. An inshore fleet makes daily trips out to a depth of 80 ft. The offshore fleet may fish for extended periods as far from shore as the continental slope. Fishing occurs year-round, usually offshore in winter and inshore in summer. The otter trawl catch was examined at McGarrigel's and at Starn's Marina in Atlantic City.

Pot fishing takes place from April through September. The average size of the pots is 46 x 22 x 26 inches. The catch from pots located 5 to 6 miles off Little Egg Inlet was examined. Black sea bass and American lobster were the primary commercial species taken; red hake, spotted hake, and scup were taken occasionally.

Gill netting occurs from May through September. Gill nets may be set just beyond the surf zone or as far offshore as 5 miles. They are usually over 600 ft long with mesh sizes ranging from 3.5 to 6 inches.

Gill nets are fished at the surface or off the bottom. The catch was recorded at Beach Haven, and at Starn's Market in Atlantic City. Bluefish and weakfish were the two most abundant fishes taken.

Commercial landings of finfishes for New Jersey generally increased in 1972 over 1971 (U. S. Department of Commerce, 1972). Landings of species which increased by 50% or more over 1971 included the following: Atlantic menhaden, tilefish, white perch, and Atlantic herring (Table 116). Silver hake ranked first by weight, whereas summer flounder ranked highest by dollar value. Catches of yellowtail flounder, butterfish, and cod declined in 1972 from 1971.

Atlantic County fish landings were examined from January, March to May, and July to December, 1972 (U. S. Department of Commerce, 1972). The total catch was 1,524, 821 lb. The five most abundant fishes included the following: weakfish (19% of the total catch), yellowtail flounder (15%), scup (14%), summer flounder (13%), and silver hake (11%) (Table 117).

The commercial catch in pounds landed at Starn's Marina (Table 118) was 15% of Atlantic County's fish landings (Table 117). The most abundant fishes landed at Starn's (1972) were scup (26%), weakfish (22%), and yellowtail flounder (20%). Most of this catch was from inshore waters.

Discussion

The following species may occur with varying frequency and abundance in the vicinity of the Site. They are important either as sport fishes, commercial fishes, or both.

American shad - This is an important migratory, anadromous fish which spawns in fresh water rivers along the Atlantic Coast. Adults may be found in the area of the Site during the spring. Approximately 800 lb. were landed at Starn's Marina in April and May of 1972. Adults were collected in this study by gill nets set in Great Bay during April. Most shad tagged off Beach Haven, Long Beach Island, were recaptured in the Hudson River (Nichols, 1958). Those young collected in the present study which over-wintered offshore in the vicinity of the Site had apparently moved south from the Hudson.

Atlantic menhaden - This is a migratory fish that is caught with purse seines. It is processed commercially for its oils and as a source of protein for animal feed. Schools of menhaden were frequently sighted during the summer in Great Bay and offshore in the vicinity of the Site. Menhaden were the most important species in the commercial catch from 1945 to the mid-1960's (Thomas et al., 1972). Except for 1970, menhaden catches have been increasing since 1966.

Silver hake - This is primarily a commercial species although it is occasionally caught by sport fishermen around wrecks or jetties, or while cod fishing offshore. It is found in the vicinity of the Site from late fall to spring and is taken commercially from January to April. Young and juveniles are occasionally abundant near the Site.

Red hake - This is a commercial species which is also occasionally caught in the area by sport fishermen. Young and juveniles were some of the most abundant demersel fish taken in the vicinity of the Site from late fall through spring. It was generally absent from the area during the summer.

White hake - This species is similar to the red hake but is much less common in the study area. Most specimens taken in this study were young which were collected in the spring and summer. Some juveniles and adults were collected during the fall. Those taken commercially are taken from offshore of the Site.

Striped bass - This species is a highly prized game fish and is one of the most important sport and commercial fishes along the New Jersey coast. The commercial landings have remained relatively stable for the last 15 years (Thomas et al., 1972). The sport fishing season extends from the first of March to the end of December, but most fishing is done during the spring and fall migration. Generally smaller striped bass weighing from 2 to 6 lb. are caught in the spring while larger bass generally weighing from 10 to 35 lb. are taken in the fall. The length-frequency distribution of 87 striped bass from the vicinity of the Site is given in Table 121. The estimated sport catch for striped bass along the Atlantic Coast during 1965 was between five and six times the 1970 commercial catch of 10.5 million lb. (McHugh, 1972).

Black sea bass - Adults and young are relatively common in the study area during the spring, summer, and fall and they are taken by sport and commercial fishermen at this time. Most are taken commercially in lobster or sea bass pots located from 1 to 20 miles from shore and are caught by hook and line around jetties and wrecks. Black sea bass were collected in lobster pots at the Site in 1972 (Table 145). This species should become abundant around the proposed Site breakwater.

Bluefish - Bluefish adults and juveniles are common during the summer and fall and are caught by sport, gill net, and otter trawl fishermen in the vicinity of the Site. McHugh (1972) reported that the sport catch for bluefish in 1965 was over 90 million lb., almost 15 times the total commercial catch. The commercial catch of bluefish in New Jersey has remained stable over the past 15 years (Thomas et al., 1972).

Bluefish measured from the sport catch in 1972 ranged from 526 to 793 mm (FL). Length-frequencies of bluefish from gill net fishermen from 1971 and 1972 are presented in Table 120.

Scup - Juveniles and adults are in the study area during the summer and early fall. This is a common sport fish particularly around wrecks and may become very common around the breakwater of the Site. It is taken commercially in offshore waters by otter trawl from March to May (David Robinson, personal communication). The length-frequency distribution of scup from the otter trawl fishery is given in Table 123.

Weakfish - Adults were found both in the bays and ocean and were taken in the vicinity of the Site from April to early November. Juveniles were taken in this area from mid-summer through the fall. Weakfish measured from the sport catch ranged from 375 to 550 mm (FL). Length-frequencies of weakfish from otter trawls and gill nets were compared for 1971 and 1972 (Table 119). Adults taken in 1972 were generally larger than those taken in 1971.

After many years of low catches, the weakfish has again become a common species in the commercial catch (Table 116). A landing of 3.1 million lb. in 1971 was the best catch recorded for weakfish within the last 23 years (LoVerde, 1972).

Tautog - This is a sport fish taken near banks, pilings, jetties, and wrecks. It is taken by pot fishermen along with black sea bass and lobster. Tautog were the most common fish collected in lobster pots at the Site. This species should become abundant around the proposed Site breakwater. Juveniles and adults occur in the study area throughout most of the year.

Atlantic mackerel - Large schools of this species migrate north in the spring generally a few miles offshore of the Site although often within several miles of shore. A few schools of young were found near the Site during the summer. Most mackerel are now caught by otter trawl. Average size of individuals taken in 1971 was 3/4 lb. (Lo Verde, 1972).

Butterfish - This species is found during late spring, summer, and fall. Adults are commercially important. LoVerde (1972) stated that landings of butterfish increased by 1/4 million lb. in 1971 over 1970. Young and juveniles were common near the Site during the summer of 1972.

Summer flounder - Adult summer flounder are taken in the bays and inshore ocean from May through early September. Commercial catches are generally made in the winter from offshore grounds. The length-frequency distribution of summer flounder taken by otter trawl fishermen is given in Table 122. Larvae are found in the vicinity of the Site during late fall and winter whereas adults are present in late spring, summer, and early fall.

Yellowtail flounder - This is an important commercial species taken by trawl during the winter. The 1971 commercial catch was 1,297,064 lb. (Table 124). Adults were collected occasionally in the present study near the Site during the winter and early spring.

Winter flounder - This is an important sport fish that is caught in the bays and waterways. Adults are found in the area during winter and spring whereas juveniles occur in the area throughout the year. It is taken by the inshore trawl fishery. Those measured from the sport catch ranged from 200 to 350 mm (TL).

Northern puffer - Adults, juveniles, and young are found in the study area from late spring to early fall. They are caught principally by sport fishermen in the bays and waterways. The northern puffer was the predominant sport fish in Great Bay during June 1969 (Hamer, 1972). The sport catch of northern puffer was low both in 1971 and 1972.

Some additional species collected in the area which are also occasionally used as food include the sandbar shark, dusky shark, smooth dogfish, American eel, conger eel, goose fish, silver perch, spot, and windowpane flounder.

Shellfisheries

Commercial populations of shellfish occur in both the ocean and bays along the New Jersey coast. The inshore fleet fishes from the surf zone to approximately 25 miles from shore. Important bay shellfisheries exist in Great Bay, Little Egg Harbor, Mullica River, and the waterways near Brigantine.

Major Ocean Shellfisheries

The Atlantic surf clam occurs along the coast from the Gulf of St. Lawrence to Cape Hatteras, North Carolina. Most surf clams are harvested more than 3 miles from shore, but during the winter clams near shore are utilized.

Most of the surf clam fleet is composed of trawlers converted for dredging purposes. The hydraulic dredge employed is constructed of an iron frame that forms the mouth, an adjustable digging blade, and a bag composed of iron rings. Water jets are directed in front of the blade to loosen the surf clams from the substrate.

The Atlantic County shellfish landings for 1972 were recorded in January, March-May, and July-December (U.S. Department of Commerce, 1972). During these ten months, 1,171,470 lb. of surf clams were harvested in the county (Table 117). Surf clam landings in New Jersey during 1972 totaled 21,331,864 lb. (Table 116). The landings in 1971 were almost 11.0 million lb. less than in 1970 (LoVerde, 1972). The length-frequency distribution of surf clams taken in 1972 with a commercial dredge ranged from 100 to 130 mm with a modal length of 115 to 119 mm. Surf clams were among the 10 most abundant species of invertebrates collected during this study in the vicinity of the Site.

The American lobster is found from Labrador to Virginia (Gosner, 1971). Meade (1969) reported that there are both inshore and offshore populations. The offshore population inhabits the edge of the continental shelf at depths from 300 to 1,200 ft. The inshore population is generally found from 2 to 15 miles from shore.

The American lobster is the most valuable shellfish per pound in the northwest Atlantic. From 1960 to 1970, landings in New Jersey increased (Thomas et al., 1972). This was due in part to climatic trends which were favorable to the growth of lobster in more southern waters (Dow, 1969) and to increased fishing effort. Until 1967 otter trawl operators accounted for 90% of the total yearly catch. In the past 4 years their take has decreased, while the catch by lobster pot fishermen has increased (LoVerde, 1972).

Lobster production in 1971 was 1.3 million lb., some 1.2 million lb. less than in 1970 (LoVerde, 1972). Landings of lobster in Atlantic County during 10 months of 1972 totaled 185,455 lb. (Table 117). New Jersey landings totaled 1,308,247 lb. in 1972 (Table 116). Seven American lobster caught in pots within 3 miles of the Site on 19 July 1972 ranged from 240 to 500 mm (rostrum to telson) with a mean length of 303 mm.

A few juvenile specimens of the American lobster were collected by trawl during this study in the vicinity of the Site. Many larvae were taken by plankton nets during July near the Site, in Little Egg and Brigantine inlets, and in Great Bay.

The sea scallop ranges from the Bay of Fundy to Cape Hatteras in depths of 50 to 550 ft. The bulk of the New Jersey catch was landed from June to November, a period when otter trawling for finfish was relatively unproductive. The New Jersey landings of sea scallop totaled 246,612 lb. in 1972 (Table 116). The 1971 landings (U.S. Department of Commerce 1972) totaled 111,803 lb. (Table 124). During 10 months in 1972, sea scallop landings in Atlantic County totaled 52,325 lb. None have been collected in this study in the vicinity of the Site.

Minor Ocean Shellfisheries

Invertebrates of minor importance commercially are the common rock crab and the Atlantic long-finned squid (Table 116 and 117). The common rock crab is edible but there is little demand for it. Usually the claws and occasionally the entire crab are sold for human consumption. Rock crabs are caught incidentally in otter trawls and lobster pots. In 1972, 90,793 lb. were landed in New Jersey (U. S. Department of Commerce, 1972). The rock crab ranked fourth in abundance of the invertebrates taken in trawl collections in the vicinity of the Site from February to December, 1972.

The Atlantic long-finned squid is caught incidentally by trawl fishermen during the summer. It is often frozen and sold as bait, but can be used for human consumption. During 1972, 412,051 lb. of squid were landed in New Jersey. This species appeared in collections in this study from May through November. It ranked third in abundance in collections from the vicinity of the Site from February to December.

Bay Shellfisheries

The hard clam inhabits the bays and estuaries. Clams are harvested from small boats with tongs, rakes, or by hand, as dredging for them in the bay is prohibited.

In 1972, the state of New Jersey sold 12,556 resident licenses and 3,135 non-resident licenses for clamming (Joseph Price, personal communication). Clamming lots range in size from one to five acres and are leased by the state to local clammers.

During January, March-May, and July-December, 1972, 657,690 lb. of the hard clam were harvested in Atlantic County. The hard clam harvest ranked highest in dollar value of the shellfishes for the county (Table 117).

New Jersey landings in 1972 totaled 2,195,733 lb. During 1971, 2,451,110 lb. of the hard clam were landed (Table 116).

The eastern oyster is adapted to life in an estuarine environment and can withstand wide variations in salinity and temperature. Optimum growth occurs in waters of 10 to 28 ppt salinity (Lossanoff, 1965).

New Jersey maintains approximately 400 acres for oyster cultivation in Great Bay and the Mullica River. Eighty acres are reserved in the Mullica River as seed beds. There was no harvesting of eastern oyster from the Great Bay and Mullica River cultivation areas in 1972.

The blue crab provides an important sport fishery in the bays. It is taken by baited traps, hand lines, and nets. Some 85,080 lb. were harvested commercially in Atlantic County during 10 months in 1972 (Table 117). New Jersey landings were 1,451,978 lb. (Table 116).

BENTHIC INVERTEBRATES

Elizabeth Van Eps-Garlo and Jeffrey J. Hondo

Introduction

Benthic invertebrates were collected in the vicinity of the Site, in Little Egg Inlet, in Marshelder Channel, and in parts of Great Bay and Little Egg Harbor. Both littoral and sublittoral zones were sampled. The littoral zone is the area between the highest high tide and the lowest low tide; the sublittoral zone extends from the lowest low tide line to the edge of the continental shelf.

The sampling program was designed to determine the species present and estimate their relative abundance in the vicinity of the Site. The ponar bottom grab, clam dredge, trawl, and lobster pot were used for quantitative and semi-quantitative sampling in the sublittoral zone. The littoral zone was sampled initially with a sieve and 0.5-m frame, and later with a plexiglass cylinder.

Sampling Program

The vicinity of the proposed Site was divided into 64, one-mile square quadrats (Fig. 3). The zone which included the Site was subdivided into nine sections. The center section (5255) was roughly equivalent to the area the proposed plant Site will cover. Areas in the bays were also divided into zones, using landmarks and buoys as lines of demarcation (Fig. 1). Stations to be sampled regularly were chosen in selected zones. Their position was established by a combination of compass bearings, visual fixes made with a sextant on charted landmarks, and Loran bearings. The use of the sextant gave the greatest accuracy but the use of Loran was necessary when weather conditions did not permit visual sightings.

Temperature, salinity, and dissolved oxygen for each collection were measured at the surface and bottom and recorded on a field sheet (Fig. 5). In addition, air temperature, secchi disc reading, and other parameters were also recorded. Sediment samples were taken at each ponar station.

Samples using all types of collecting gear except the trawl were taken monthly in the ocean, bays, and inlets. Trawl samples were taken twice a month in the ocean.

Materials and Methods

Beach Sieve

Intertidal invertebrates were sampled semi-quantitatively with a 0.5-m^2 frame, shovel, and sieve. At each station, four 0.5-m^2 quadrats were taken in a transect extending from approximately the mean high water line to the sublittoral zone. The quadrat frame, which was equipped with a 4-inch cutting edge, was pressed into the substrate. The sand or mud was removed and placed in a 1-mm mesh sieve. The sample was washed in the field, large shell fragments and stones were discarded, and the remaining organisms were relaxed and preserved. Initially samples were taken at a variety of stations, from which five locations were later selected for regular sampling (Table 25).

After September, 1972, a coring device was introduced to obtain a quantitative sample of beach sand. A 93.6-mm diameter plexiglass cylinder with a rubber stopper was inserted 13 cm into the sand. Four such cores sampled an area of 0.12 m^2 and yielded a total sample of 3.8 liters. The sample was sieved using a 1-mm mesh net set in a frame. The net which contained the sample was removed from the frame and placed in a jar of 10% $MgCl_2$ and seawater.

Ponar Bottom Sampler

Quantitative benthic samples were taken in the ocean, inlets, and bays with a ponar bottom sampler. The ponar sampled an area of 23 x 23 cm or .05 m^2. Thirty pounds of weights were added to the ponar frame to facilitate its penetration of the substrate found in the study area. The sampler was lowered from a vessel by means of a davit and electric windlass. Upon retrieval, the samples were put into calibrated buckets and the sample volume was recorded. Samples smaller than 1.4 liters were discarded. The sample was gradually poured into a 1-mm nylon mesh net set in a wooden frame, and was washed with running sea water. All material was carefully hand gleaned from the sieve, and was placed in a jar of 10% $MgCl_2$ and seawater.

Nine stations were sampled monthly with the ponar bottom sampler (Table 125). Three stations were within the one square mile quadrat which surrounds the Site, three were in Little Egg Inlet, two were in Marshelder Channel, and one was in Little Egg Harbor. In addition to the three regularly sampled ocean stations, samples were taken each month from selected areas either north, south, or west of the Site (Fig. 3). A randomly located transect was sampled quarterly in each of the three areas. A tentative control area was established about 2.8 nautical miles south of the Site and about 2.5 nautical miles off Brigantine Inlet. This area has a sand ridge which appears to be similar to the Ridge near the Site.

Clam Dredge

Large, slow moving infauna were collected with a dry commercial clam dredge. The dredge frame was 3 x 2 x 1 ft. A 3.5-ft long bag of 1.5-inch stretch mesh was fastened to the frame. The blade dug into the bottom to a depth of 6 inches. The dredge was originally designed for use by the surf clam fleet to test a potential clamming area, and was a good sampling device for the study area. The dredge was lowered and retrieved from the boat by means of a davit and electric windlass.

Initially all samples were made randomly, but at present monthly collections are taken at the same stations as ponar collections described above (Table 125). One 5-minute haul was made at each station. The clam dredge was usually towed in the direction of the wind or tide. The distance towed depended on the bottom type. In fine, closely packed sand the distance was shorter during the 5-minute period than in soft mud. Distance towed ranged from 20 to 100 meters.

Trawl

Macroinvertebrates were separated from the fishes taken with a 25-ft semiballoon trawl in the vicinity of the Site. The trawl collected motile benthic epifauna and shallow burrowing infauna. The net was selective towards larger organisms. The area sampled by each trawl haul was estimated to be 4,671 m^2 (see section on Fish, Ocean Trawl).

Lobster Pot

From August through October, two lobster pots were placed at the Site. Each pot was approximately 46 x 22 x 26 inches, and was constructed of wood slats set 1 inch apart. One side was constructed to form a funnel which provided an entrance to the pot. During storms the pots were moved, and on September 15, one was lost. The pots were not baited. They were pulled and emptied eight times a month and reset in the same location.

Laboratory Procedures

All organisms were counted and identified. Nomenclature usually followed that of Gosner (1971). Amphipods were identified to species by Ms. Ann Frame of the Sandy Hook Marine Laboratory, Highlands, New Jersey.

The organisms collected with the beach sieve and ponar grab, and small organisms collected from trawl and clam dredge samples were relaxed in 10% $MgCl_2$ and seawater for 1 to 5 hours. Samples were fixed in 10% formalin for 24 to 72 hours, washed, and then transfered to a solution of 70% isopropanol and 5% glycerol. Ponar samples were stained with rose bengal, a proteinaceous dye, to facilitate separation of organisms from the sediment. Organisms from trawl and clam dredge collections were fixed in 10% formalin for 1 to 5 days, washed, and then preserved in 40% isopropanol.

Invertebrates from selected ocean trawl collections taken in November and December were weighed. Those samples weighed were taken in the zone seaward of the Ridge, on the Site, and in the zone landward of the Site. Wet weights of preserved specimens of each species were determined to the nearest 0.1 gram with an O-Haus triple beam balance.

Statistical Procedures

Each ponar collection represents one drop with the ponar bottom grab, or an area sampled of .05 m^2. One drop was made per station during 1972 to facilitate the sampling of a wide variety of areas. On 15 September, 10 successive drops were made at the Site. A plot of the cumulative number of species collected versus number of drops for these 10 samples is shown in Fig. 23. The first grab sampled approximately 23% of the species and 5 grabs sampled 90% of the species taken in 10 grabs. Five grabs per station will be taken in 1973.

Brillion's measure of species diversity,

$$H=1/N\ (\log_2 N! - \sum_{i=1}^{n} \log_2 N_i!)$$

Where, H=species diversity of a sample
N=total number of individuals in a sample
N_i=number of individuals of the i'th species
n=number of species

was used to calculate the Diversity Index (H) for all ocean ponar samples (Appendix Table 34). This index was used in preference to the more commonly employed Shannon-Weaver Species Diversity Index which assumes that the collection is a random sample from a larger population. Brillion's measure assumes that the sample is a population in itself and can only be used for collections in which discrete individuals can be counted (Pielou, 1966a). Seasonal species diversity was found by computing the values for all collections during the season and calculating their mean and standard deviation. The yearly mean H value for a specific station was determined by computing the mean value for all collections from that station.

A standard t-test was used to compare yearly mean values of H for any two localities.

Results

Results are discussed by gear and area. Table 126 lists those macroinvertebrates collected during 1972.

Physicochemical and biological data for each invertebrate collection taken in 1972 are listed by gear and area in Appendix Tables 34-46. Data from ponar collections have been arranged by the following areas: Ocean (Appendix Table 34), Inlet (Appendix Table 35), Great Bay (Appendix Table 36), and Little Egg Harbor (Appendix Table 37). Data from clam dredge collections have been organized by the following areas: Ocean (Appendix Table 38), Inlet (Appendix Table 39), Great Bay (Appendix Table 40), and Little Egg Harbor (Appendix Table 41). Invertebrates tabulated from trawl collections in the ocean appear in Appendix Table 42.

Beach Sieve

Thirty-six of the sieve collections taken from ocean beaches in 1972 were analyzed and yielded 7,480 specimens (Appendix Tables 43-46). The number of species found was relatively small. Bay beaches had well developed polychaete communities composed mainly of the families Spionidae (suspension feeders), Orbiniidae (deposit feeders), and Glyceridae (detritus feeders). Suspension feeding amphipods of the family Ampeliscidae were abundant in a few areas but were not as ubiquitous as polychaetes.

Organisms collected on ocean beaches, in order of abundance, were Scolelepis squamata (polychaete worm), haustoriid amphipods, Emerita talpoida (mole crab), and Donax fossor (wedge clam). S. squamata comprised more than 80% of the specimens collected. They generally occurred in areas near the low tide line where exposure to waves was minimal. Haustoriid amphipods and mole crabs appeared to follow the water line as the tide changed. The wedge clam established localized communities in the summer, but was rare in the winter. Polychaete worms, and mole crabs increased in number during the summer. The surf clam, lady crab, and common rock crab occurred sporadically in small numbers.

The few species which dominated the beach community had well defined seasonal changes in abundance. In 1973 the beach habitat will be sampled just once during each season.

Ponar Bottom Grab

Twenty-two samples collected from March through December in a 1/3-square mile area on and adjacent to the Site (zones 5254-5256) yielded a total of 952 specimens representing 78 taxa (Table 127). The average density of all species combined was 636 specimens/m^2. Species diversity of these collections varied from 0.75 to 1.98, with a mean of 1.33, and standard deviation of 0.40.

The surface layer of sediment on the Site was composed of fine to medium sand with less than 2% silt. Over the 10-month period bivalves were the dominant group and composed 36% of the community. The Atlantic surf clam, Spisula solidissima (113/m^2), was the dominant member of the community. The northern dwarf tellin, Tellina agilis (59/m^2) and the nut clam, Nucula proxima (55/m^2) were also abundant bivalves. Polychaete worms were the second most abundant group and composed 24% of the organisms collected. The vast majority of the polychaetes collected were capitellid polychaetes (39/m^2) and Goniadella gracilis (24/m^2). Amphipod crustaceans comprised 19% of all animals collected. Gammarus annulatus (66/m^2) was the most abundant amphipod in ponar collections; Batea catharinensis (21/m^2) and Corophium tuberculatum (14/m^2) were also common.

A total of 10 samples was collected from a 1/3-square mile area on the Ridge (zones 5251-5253) from March through December. The average density of all specimens combined was 236/m^2. A total of 118 specimens of 34 taxa was collected (Table 128). Species diversity ranged from 0.37 to 1.81, with a mean of 0.90, and a standard deviation of 0.41.

Surface sediments of the Ridge were medium to coarse sand, shell fragments and less than 1% silt. About 25% of the organisms were bivalves, mainly the Atlantic surf clam ($42/m^2$) and northern dwarf tellin ($14/m^2$). Polychaete worms comprised 14% of the organisms collected on the Ridge. *Goniadella gracilis* ($12/m^2$) was the most common polychaete. Amphipods, predominately haustoriids, composed 6.7% of the organisms. Numbers of organisms were greatest in spring and summer when polychaetes and amphipods reached maximum abundance.

Twelve samples were collected within a 1/3-square mile area landward of the Site (zones 5257-5259) between March and December (Table 129). A total of 6,860 specimens representing 54 taxa was collected at an average density of $11,433/m^2$. Species diversity indices ranged from 0.37 to 1.69 with a mean of 1.25 and standard deviation of 0.40.

The bottom substrate of the zones landward of the Site was composed of fine sand and mud. Polychaetes comprised 93.3% of the benthic community. The majority of these was represented by two families, Capitellidae ($5,173/m^2$) and Ampharetidae ($5,077/m^2$). *Tharyx acutus* ($135/m^2$) and *Paranaitis speciosa* ($103/m^2$) were also common. Bivalves composed 3.3% of the organisms collected with the northern dwarf tellin ($220/m^2$) and Atlantic surf clam ($80/m^2$) the prevalent forms. Less than 1% of the community was composed of amphipods, the most common of which was *Protohaustorius deichmannae* ($263/m^2$). Density of organisms was greatest in the summer when the numbers of polychaetes dramatically increased.

Thirty ponar samples taken in Little Egg Inlet between March and December, 1972 (Table 130) yielded 1,493 specimens of 68 taxa. Most samples were from flat, sandy areas near beaches or sandbars. The channel bottom was generally covered with shell fragments which hindered use of the ponar. The average density of all specimens combined was 995/m^2.

The surface sediment in Little Egg Inlet was generally fine to coarse sand, with an extremely low silt content. Areas of clay were encountered on the sides and bottom of channels. Over the 10-month period, bivalves were the dominant group and comprised 53% of the specimens by number. This high percentage of bivalves was due to the presence of the common blue mussel (Mytilus edulis) which formed dense aggregations. One sample of the common blue mussel taken in a channel raised the total percentage of bivalves by a factor of 3. If that collection is excluded from the yearly totals, bivalves formed only 16% of the community found on sandy bottoms between channels. The northern dwarf tellin (67/m^2) and Atlantic surf clam (12/m^2) were the two most common bivalves. Amphipods composed 38% of the specimens collected in the inlet. Protohaustorius deichmannae (130/m^2) was the most abundant form and was often collected in association with Acanthohaustorius millsi (18/m^2). Batea catharinensis (81/m^2) ranked second in abundance in inlet samples and Parahaustorius longimerus (30/m^2) ranked third. Polychaete worms formed only 3% of the inlet community. Suspension feeding spionids and the carnivores, Nephtys bucera and Nephtys picta, were among the most common forms. The greatest number of organisms was collected in October (Table 131).

Twenty ponar samples taken in Great Bay between March and September yielded 3,885 specimens of 89 taxa (Table 132). Most samples were taken from the intracoastal waterway where there were high percentages of mud. The average density of all specimens collected was 3,884/m^2.

Amphipods were the dominant group and composed 63% of the specimens collected. Ampelisca abdita was the most common species and averaged 1,821/m^2. Amphipods reached maximum densities in April and August; the highest density recorded was in April when they averaged 7,706/m^2 (Table 133). In sandy areas haustoriid amphipods, especially Protohaustorius deichmannae (184/m^2), were common. Polychaetes composed 21% of the specimens; Streblospio benedicti ($248/m^2$) and capitellids ($221/m^2$) were the most numerous forms. Bivalves composed only 10% of the organisms collected. Small specimens of the Atlantic surf clam ($155/m^2$), and the northern dwarf tellin ($123/m^2$) were most common.

Only a few samples were taken from the lower portion of Great Bay and the Mullica River. The results of a study of the benthos of this area were reported by Durand and Nadeau (1972).

Clam Dredge

From June through December, 44 collections taken near the vicinity of the Site yielded 8,825 specimens representing 50 taxa (Table 134). These data are summarized by month in Table 135. The Atlantic surf clam, Spisula solidissima, comprised 81% of all specimens collected. Components of this community and their relative abundance were as follows: Spisula solidissima (7,221 specimens; 164 specimens per collection), Echinarachnius parma (774; 18), Polinices heros (142; 3), Cancer irroratus (133; 3), Polinices duplicata (129; 3), Diopatra cuprea (157; 1), Lumbrineris fragilis (56; 1), Asterias forbesii (51; 1), and Ovalipes ocellatus (37; 1).

The Atlantic surf clam was frequently collected at the Site and on the Ridge. The average number per haul was about 200. Most specimens ranged in length from 20 mm to 125 mm. One third of the collections contained surf clams of commercial size (greater than 100 mm) and specimens were taken from water 25 ft in depth or less. The average number of commercial size Atlantic surf clams was five per haul in which they occurred. The greatest density encountered was 2,367 per haul from the top of the Ridge in June. The vicinity of the Site is not used for commercial clamming at present.

Echinarachnius parma, the sand dollar, ranked second in abundance but was unevenly distributed. In September, 568 specimens were collected in one haul taken approximately 1.5 nautical miles north of the Ridge (Table 135). The density on the Site ranged from 0 to 13 individuals per haul (Appendix Table 38).

The clam dredge took predominately larger organisms because of the relatively large mesh size of the bag. Diopatra cuprea was the dominant polychaete and was the only sedentary tube-forming species taken. All of the other 24 polychaete species collected with the clam dredge in the ocean were burrowing forms.

A total of 29 clam dredge collections was taken in Little Egg Inlet in 1972 (Tables 136 and 137). The bivalves, Mytilus edulis (17,307 specimens, 597 specimens per collection), and Spisula solidissima (3,375; 116) accounted for 90% of all specimens collected. The next eight most abundant species were Cancer irroratus (230; 8), Crepidula fornicata (186; 6), Ovalipes ocellatus (136; 5), Libinia emarginata (128; 4), Asterias forbesii (102; 4), Pagurus longicarpus (93; 3), Crepidula plana (83; 3), and Neopanope texana (50; 2). The encrusting polychaetes, Sabellaria vulgaris and Hydroides dianthus, were frequently found in localized areas and were attached to shell rubble.

Clam dredge collections from the Inlet indicated that the Atlantic surf clam dominated areas of level sandy bottom and that the common blue mussel often dominated on the bottom and sides of channels.

In Great Bay, nine collections made with the clam dredge yielded 181 specimens representing 22 taxa (Tables 138 and 139). Bivalves dominated and comprised 72% of the organisms collected. The three most prevalent bivalves were Mercenaria mercenaria (119 specimens; 40 specimens per collection), Ensis directus (9; 1) and Anadara ovalis (3; 0.3). Hauls in adjacent areas yielded from 0 to 84 hard clams per collection (Appendix Table 36) and exemplified their uneven distribution in the Bay. Polychaetes ranked second in percentage composition and mud crabs of the family Xanthidae ranked third (3% of the total). The large percentage of silt and clay in the Bay sediments made it difficult to use the clam dredge and samples generally contained few organisms.

Thirteen hauls of the clam dredge taken in Little Egg Harbor from September to December yielded more than 800 specimens of 39 taxa (Tables 140 and 141). Three bivalves, Mytilus edulis (500 specimens; 39 specimens per collection), Mercenaria mercenaria (100; 8), and Anadara ovalis (6; 0.5); three polychaetes, Hydroides dianthus (40; 3), Diopatra cuprea (19; 2) and Glycera americana (14; 1); and three decapods, Neopanope texana (23; 2), Cancer irroratus (12; 1) and Eurypanopeus depressus (10; 1) accounted for 80% of the specimens collected.

Areas adjacent to the channels in Little Egg Harbor are privately leased for cultivation of hard clams and were not available for dredging; thus these data do not reflect the population density or community structure on cultivated lots.

Trawl

In 1972 a total of 161 ocean trawl collections contained an average of 309 invertebrate specimens per collection (Tables 142 and 143). More than 49,488 specimens representing 147 taxa were collected from February through December (Table 142).

The 10 most abundant macroinvertebrates from trawl collections in the vicinity of the Site were the snapping shrimp, Crangon septemspinosa (32,335 specimens; 202 specimens per collection); sand dollar, Echinarachnius parma (5,544; 35); Atlantic long-finned squid, Loligo peali (3,259; 20); common rock crab, Cancer irroratus (2,192; 14); New England nassa, Nassarius trivittatus (1,350; 8), common starfish, Asterias forbesii (1,282; 8); hermit crab, Pagurus longicarpus (1,193; 8); lady crab, Ovalipes ocellatus (798; 5); Atlantic surf clam, Spisula solidissima (336; 2); and northern moon snail, Polinices heros (238; 2).

Relative biomass data from 16 trawl collections taken in November and December are presented in Table 144. Decapods and echinoderms comprised 99% of the weight of invertebrates collected in the vicinity of the Site in November and December. The remaining 1% (polychaetes, mollusks, etc.) were small organisms which were not sampled adequately with this gear. Although the common rock crab comprised only 5% of the total number of specimens, it accounted for 70% of the total weight of organisms collected in November and December. The snapping shrimp ranked first by number but was only 3% of the total weight in November and December. The sand dollar and common starfish were the only echinoderms collected, and totaled 17% of the weight.

The Site yielded fewer common rock crabs per haul and in general, less grams per m^2 of macroinvertebrates than the other ocean regions. The common rock crab averaged .23 g/m^2 at the Site and .36 g/m^2 for all ocean collections. The weight of all specimens collected in November and December in the vicinity of the Site was .52 g/m^2 and .36 g/m^2 in the Site zone 5255. These values reflect the standing crop of decapods and echinoderms which were collected most efficiently by trawl.

Lobster Pot

Thirteen collections taken with lobster pots in the vicinity of the Site between August and October yielded 272 specimens representing 21 taxa (Table 145).

The common rock crab ranked first numerically and accounted for 41% of the specimens collected. The white slipper limpet (Crepidula plana) was second in abundance. It is the common epifauna on hermit crab shells. Two fishes, the tautog and black sea bass, ranked third and fourth numerically. This program will be expanded in the spring of 1973.

Discussion

Those species from the study area of particular importance either numerically or because of their utilization by man, are discussed below in phylogenetic order. Parasites collected in the study area are briefly discussed.

1. Polinices heros and Polinices duplicata, moon snails, were abundant in the ocean and were occasionally taken by dredge in the Inlet. They are voracious carnivores which prey principally upon bivalves and are frequently found on surf clam beds. They bore a hole through the prey's shell and eat the meat within. The impact of predation on surf clam populations is not known (Yancy and Welch, 1968).

2. Mytilus edulis, the common blue mussel, is the dominant species in areas of the inlets and Marshelder Channel where large mussel beds exist. It is commonly found on the sides and bottom of channels and on marsh banks with hard substrates. The blue mussel is a suspension feeder and depends on water currents to carry food particles to it. It is eaten by a wide variety of animals including diving ducks, fishes, crabs, snails, and starfish. Blue mussels are also consumed by people.

The blue mussel attains a size of about 76 mm (Abbott, 1954). Chanley and Andrews (1971) reported that in Virginia it spawns from January through

November. Its larvae were collected in the bays, inlets, and in the vicinity of the Site in large numbers in the fall. No adults were collected near the Site, where a hard substrate is absent.

3. Mercenaria mercenaria, the hard clam, is an abundant species in the bays (Great Bay, Little Egg Harbor, Little Sheepshead Creek). It is a suspension feeder, and in turn is eaten by larger organisms including crabs, birds, and fishes. The hard clam may reach a maximum size of 127 mm (Abbott, 1954). In Virginia, it spawns from May through October (Chanley and Andrews, 1971).

There is an extensive year round fishery for the hard clam in southern New Jersey. Clams are sold alive locally and are also trucked to more distant areas.

4. Spisula solidissima, the Atlantic surf clam, ranked first in numerical abundance in the vicinity of the Site and second in the Inlet, in collections made with the ponar and clam dredge. Those collected in the study area ranged from 1 to 125 mm but it can reach a length of 178 mm (Abbott, 1954). Size frequencies for surf clams collected by clam dredge in the ocean and Inlet from June to December, 1972, are presented in Table 146. Excluding December, average growth for clams from the vicinity of the Site was 3.4 mm per month. Those collected in the Inlet seemed to represent several different populations; thus the mean length for each month in Inlet samples was representative more of sampling location than growth.

The surf clam in New Jersey spawns from mid-July through mid-August. It may spawn again from mid-October through early December (Yancy and Welch, 1968). Spawning time may vary annually and with geographic location. Larvae are planktonic for three weeks or more before they settle to the bottom (Carriker, 1967).

The surf clam feeds on suspended organic material from the water-substrate interface. It is an important food source for fishes, diving ducks, gulls, and is used for human consumption.

A fleet of approximately 100 vessels from New Jersey dredge for surf clams. Vessels from other states also fish off the New Jersey coast. The clams are usually sold to companies such as Howard Johnson and Snow Food Products which can or freeze them. Some 27,893,366 lb. of meats valued at $3,753,822 were harvested in 1971 from New Jersey (LoVerde, 1972).

A survey of the inshore clam population along the New Jersey coast was conducted by Rutgers University and the National Oceanographic and Atmospheric Administration in 1972. Results indicate that the area from Absecon Inlet to Beach Haven Inlet has the highest recruitment of Atlantic surf clams in the state and a recommendation was made to close it to commercial dredging operations (Harold Haskins, personal communication).

5. *Tellina agilis*, the northern dwarf tellin, was among the most abundant species collected in benthic samples from the ocean and Inlet. Like the surf clam, it is a suspension feeder. It reaches a maximum size of 12 mm (Abbott, 1954). In Virginia, it spawns from April through August (Chanley and Andrews, 1971).

6. The only truly migratory invertebrates collected in the study area were two species of squid, *Loligo peali*, the Atlantic long-finned squid and *Lolliguncula brevis*, the brief squid. The Atlantic long-finned squid, appeared in May, was most abundant in August, and was largely absent by September. The brief squid first appeared regularly in August and increased in number during September. Squid prey on fish and various invertebrates and are preyed on by other fish. Squid which are caught incidentally in summer catches of trawl fishermen are sold as bait and used for human

consumption. They spawn in the vicinity of the Site during the spring and summer and their gelatinous egg cases have been found in the vicinity of the Site.

7. Glycera capitata, G. americana and G. dibranchiata (bloodworms), were frequently collected in ponar samples both in the bays and ocean. G. capitata and G. americana undergo a change of body form during the breeding season and swim to the water surface to breed. Their larvae are pelagic for a few days. They are burrowing, detritus feeders and prefer areas which have high percentages of silt and organic matter. Specimens as large as 10 cm were collected in 1972.

8. Goniadella gracilis is a small (less than 5 cm) burrowing carnivorous polychaete that was abundant in some ocean areas and at the Site. Its body becomes modified during the breeding season and it swims to the surface to spawn. It produces pelagic larvae.

9. Nephtys bucera and N. picta, sand worms, were frequently collected in sandy areas. They are predatory burrowers that appear on the substrate surface occasionally. Their larvae are planktonic and the adults are usually collected in sand with low silt content. Specimens larger than 15 cm were occasionally collected.

10. Polychaetes of the family Capitellidae are generally minute; the largest specimen collected in 1972 was 40 mm and the majority were 10 mm or less. At least one species, Heteromastus filiformis, was found in this area. It is burrowing deposit feeder which prefers areas of high silt. Capitellid polychaetes were encountered in densities as high as $45{,}000/m^2$ seaward of the Ridge in May.

11. Two polychaete species of the family Ampharetidae, Asabellides oculata and Hypaniola grayi, were collected in the vicinity of the Site.

They are small (about 20 mm) suspension feeders which build mud-mucus tubes. They were found in densities as high as 45,550/m^2 landward of the Site in May.

12. Diopatra cuprea is a large, sedentary carnivorous polychaete that constructs a tube of shell-rubble in sandy ocean areas and a tube of vegetable material in the bays. Its larvae have a short pelagic existence.

13. Two species of calcareous tube forming polychaetes, Sabellaria vulgaris and Hydroides dianthus were collected. They are suspension feeders and prefer hard substrates upon which to make their tubes. These two species can exist together in the same masses of tubes.

14. Amphipods of the family Haustoriidae were the major component of the Inlet community. They were common on the Ridge and were also collected along ocean beaches. They are suspension feeders which have body appendages adapted for burrowing, and mouth parts for filtering minute food particles from interstitial water of bottom sediments (Bousfield, 1965). They are important as secondary producers, and are used as food by larger organisms such as fish. Among the most frequently collected amphipods were Protohaustorius deichmannae (6.0 mm maximum length), Acanthohaustorius millsi (8.0 mm maximum length), and Parahaustorius longimerus (9.5 mm maximum length).

15. The amphipod, Ampelisca abdita (8.2 mm maximum length) was the most abundant benthic invertebrate collected in Great Bay. It is a suspension feeder, and has been found commonly in the stomachs of fish from the Bay. Durand and Nadeau (1972) reported that A. abdita constructed tubes which covered large areas of the bottom and thereby helped stablize bottom sediments.

16. Crangon septemspinosa, the snapping shrimp, ranked first by number in trawl samples from the ocean, and was common in collections in the bays. Preliminary data indicate it moved out of the bays in winter to warmer ocean waters.

Williams (1965) stated that snapping shrimp reached a maximum length of 70 mm in Delaware Bay, and that the breeding season there was from March to October. Eggs reared in the laboratory hatched after 6 or 7 days at 21 C. Gravid females were collected in the vicinity of the Site from February to March and in November. After a planktonic larval stage, snapping shrimp settle to the bottom. Saunders et al. (1962) found that snapping shrimp ate small bottom plants and animals. Snapping shrimp collected in the vicinity of the Site have been noted with half-ingested polychaetes in their mouths. This species is an important source of food for a wide variety of fishes and is occasionally consumed by humans.

17. Cancer irroratus, the common rock crab, ranked fourth in abundance in trawl collections in the ocean, and comprised 70% of the weight of invertebrate specimens taken there in November and December. It reaches a size of 140-160 mm (Gosner, 1971). Gravid females were taken in the vicinity of the Site from April to June and in November and December. Its larvae are planktonic, and the young crabs settle to the bottom, where they are primarily scavengers. It is of minor importance as a commercial species, and is caught incidentally by trawl and lobster pot.

18. Echinarachnius parma, the sand dollar, ranked second in abundance in trawl collections from the vicinity of the Site and was absent from the bays and inlets. It is a shallow burrowing form which constantly overturns sand to feed on microflora and detritus. It is eaten by some animals such as the benthic fish, the eelpout.

19. The starfish, Asterias forbesii, ranked among the 10 most numerous organisms collected with the clam dredge in the Inlet and ocean. It is a predator and feeds primarily on bivalves such as the Atlantic surf clam and the common blue mussel.

20. Six species of parastic invertebrates were collected in 1972: Branchellion ravenelli, Lernaeenicus radiatus, Cirolana concharum, Cirolana polita, Aegathoa medialis and Probopyrus pandalicola. B. ravenelli is a marine leech and was usually found on the bullnose ray, Myliobatis freminvillei. C. concharum and C. polita are carnivorous isopods which scavenge the bottom and are parastic on fish. C. concharum was found both free-living and attached to the gills of fishes collected in the vicinity of the Site. Aegathoa medialis is an isopod occasionally found attached to various fishes. Probopyrus pandalicola, an isopod, is an obligate parasite of the grass shrimp, Paleomonetes. The large parasitic copepod Lernaeenicus radiatus was common in the bays, particularly in areas behind Brigantine Island. It was usually attached to the bay anchovy, but was also found on 12 other species of fish.

Ocean beaches are a harsh environment subject to alternating periods of exposure to air and direct wave action. This habitat is rather uniform and the number of species that can exist there is small. The polychaete, Scolelepis squamata, is well adapted to this habitat and builds sand tubes which help protect it from waves and desiccation. It was present in densities as high as $3,883/m^2$. There seemed to be no obvious biological differences between populations of invertebrates found on an erosional beach of medium sand (Holgate) and an accretional beach of fine sand (Brigantine). Occasionally, large quantities of the moon snail, common rock crab, and Atlantic surf clam were found washed up on the ocean beaches of southern Long Beach Island and northern Brigantine after strong northeast winds.

Bay beaches were more diverse than ocean beaches and were not as dominated by relatively few species. They supported rich communities composed of bivalves, polychaetes, and crustaceans.

The majority of forms taken in the vicinity of the Site with the trawl and clam dredge were collected year-round. The following were the most abundant species: Crangon septemspinosa (32,335 specimens), Spisula solidissima (7,557), Echinarachnius parma (6,318), Loligo peali (3,259), Cancer irroratus (2,325), Nassarius trivittatus (1,364), Asterias forbesii (1,333), Pagurus longicarpus (1,210), Ovalipes ocellatus (835), and Polinices heros (380). The squids, Loligo peali and Lolliguncula brevis, were the only invertebrates which made migrations along the shore, and were present in the ocean study area from May through November. The lady crab, Ovalipes ocellatus, was not collected in the ocean during winter.

Seasonal variations were evident among some of the year-round resident species. The mollusks, Spisula solidissima, Polinices heros, and Nassarius trivittatus increased in number in spring and summer (Table 134). Massé (1972) reported that seasonal changes of bivalve mollusks, amphipods, and polychaetes were generally correlated with reproductive and recruitment processes which could cause important changes in population density. Young et al. (1971) also reported that a vast increase in mollusk abundance occurred in depths less than 15 m in Cape Cod Bay during spring and summer. In the fall and winter the common starfish and sand dollar were more abundant near the Site. The sand dollar was commonly found seaward of the Ridge at depths of 40 ft or more throughout the year.

Collections on the Ridge yielded few organisms of few taxa. The mean species diversity for 10 collections from March to December was 0.90. Coarse sediments, low percentages of silt, and surge from wave action may combine to restrict the species richness and density of organisms on the Ridge.

The Site had a species diversity (1.33) which was significantly greater (P= .05) than that of the Ridge. The Site had finer sediments and higher percentages of silt than the Ridge. It was subjected to less wave action and supported a diverse community dominated by the Atlantic surf clam and the northern dwarf tellin. The surf clam grows rapidly, matures early, and has a short life span (Thorson, 1957). Its population may therefore fluctuate enormously from year to year.

The station landward of the Site also had a higher species diversity (1.25) than that of the Ridge. Some 91% of the species which occurred at the Site also occurred landward of the Site, but in different densities and proportions. The majority of the organisms landward of the Site were polychaetes of the families Capitellidae and Ampharetidae. The numbers of these polychaetes increased dramatically in spring and summer, at which time they formed 93% of the specimens collected.

Clam dredge collections from the Inlet indicated the presence of two communities associated with different substrates. Hard substrates such as clay and shell rubble existed along the channel banks and bottom and provided an ideal place for attachment of the common blue mussel. Swift moving currents bring a constant supply of food and prevent siltation. These conditions are good for the growth of sessil forms and the dispersion of larvae. Since the blue mussel forms dense aggregations, it was the dominant species in localized areas. Associated with it were *Asterias forbesii*, *Neopanope texana*, and the calcareous tube-forming polychaetes, *Sabellaria vulgaris* and *Hydroides dianthus*.

The bottom of the Inlet was mostly sand and silt. The surface layer of sediment was fine to coarse sand exposed to strong tidal currents and surge from wave action. The Atlantic surf clam composed 90% of the organisms collected with the clam dredge in this area. Associated with it were the common rock crab, lady crab, and hermit crab.

Amphipods composed 38% of the benthic community in ponar samples from shallow sandy areas of the Inlet, whereas ocean areas were dominated either by bivalves or polychaetes. The haustoriid amphipods, *Protohaustorius deichmannae*, *Acanthohaustorius millsi*, and *Parahaustorius longimerus* were the most common forms. Polychaetes formed a small percentage of the community.

Species composition changed rapidly between the scoured sand bottoms of the Inlet and the silt-sand bottoms of the bay. Clam dredge collections indicated that as percentages of silt and clay increased, percentages of the hard clam, Atlantic jacknife clam, and blood ark also increased. Polychaetes were common and mud crabs of the family Xanthidae were present.

Ponar collections also demonstrated the diverse communities which exist in some bay habitats. Areas with high percentages of silt and clay supported very high densities of the suspension feeding amphipod, *Ampelisca abdita*; polychaetes of the family Capitellidae were numerous. In areas composed of fine sand, *Protohaustorius deichmannae* was most abundant.

PHYTOPLANKTON AND PROTOZOA

James H. Currie

Introduction

All passively drifting microscopic single-celled algae are referred to as phytoplankton. As primary producers, they serve as an important link in the aquatic food chain.

Some of the protozoa are pigmented autotrophic forms while others are colorless heterotrophs. The pigmented photosynthetic forms are a part of the phytoplankton.

The main objective of the present study is to identify the major components of the phytoplankton-protozoa community and to determine the temporal and spatial distribution of the standing crop. A study of the major inorganic nutrients has been undertaken simultaneously as a possible means of explaining some of the fluctuations in populations and community structure.

Materials and Methods

Sampling for phytoplankton, protozoa, and nutrients was begun in May, 1972. The number of stations routinely sampled included the following: ocean (4), Little Egg Inlet (1), Great Bay (3), Mullica River (2), Little Egg Harbor (3), and the Brigantine portion of the intracoastal waterway (2). These were generally sampled twice monthly. Several of the recommendations of Holmes et al. (1969) were modified and incorporated into the sampling procedures.

Surface water collections were made with either a plastic bucket or Niskin water bottle. In addition, 1.7- and 5.0-liter water bottles were used in the vicinity of the Site and at certain bay and river locations to obtain quantitative samples from discrete depths. Aliquots of the same water sample were immediately preserved with at least two different fixatives to best maintain the morphological integrity of as many different groups as possible. Fixatives used included buffered formaldehyde (3-6% formalin), buffered gluteraldehyde (2-3%), and Lugol's solution. These samples are being quantified with the aid of various settling techniques, and counting chambers such as the Sedgwick-Rafter and Palmer-Maloney cells.

During the first six months of sampling, approximately 50 ml of untreated water was retained from all surface and some bottom samples for subsequent filtration through membrane filters. The plankton was collected on 25-mm, 0.8-micron porosity Millipore filters. These samples were washed with 75, 50, 25, and 10% sea water and finally with slightly basic distilled water. The filters were then either dried in a desiccator over silica gel or dehydrated with successive (10, 30, 50, 75, and 95%) aqueous ethanol washes. Many dried filters were stained with alcoholic Fast Green (0.1% in 95% ethanol) for about 10 minutes and then rinsed with absolute ethanol. The filters were cleared with xylene and permanent slide mounts were prepared using Kleermount (Carolina) mounting media. An auxillary technique was employed in some instances whereby freshly filtered samples were treated with Millipore immersion oil, allowed to dry over silica gel, and made into permanent mounts. One drawback to the menbrane-filter technique is the loss of both naked and delicate species due to physical damage. This disadvantage is offset, however, by the retention of the less fragile forms such as most diatoms and armored dinoflagellates which can then be quantified using a compound microscope. Quantification of the more robust phytoplankton collected by the membrane-filter technique will thus serve as a check on the results obtained by enumeration of these forms in the preserved samples.

Starting in late August live sample aliquots were routinely collected at most stations. These were qualitatively examined microscopically in order to determine the extent of morphological change and the possible loss of cells during the various collection, preservation, and enumeration procedures.

A 15-cm nannoplankton net of 10-micron mesh was used for a qualitative surface collection at each station. A 1/4-m, 79-micron mesh net was used from August to October (prior to the use of a 20-mesh net for zooplankton sampling) at the Site and Little Egg Inlet stations in order to sample the entire water column for larger phytoplankton and protozoa. Larger and rarer species will appear more frequently in small mesh (less than 100 microns) net samples than in smaller volume water samples.

Duplicate water samples for analysis of nitrate, nitrite, ammonia, silicate and phosphate were collected in small plastic (or polyethylene) and glass vials. Prior to analysis the samples in plastic vials were frozen and those in glass refrigerated. Nutrient analysis was performed on a Technicon, Inc. Autoanalyzer II with standard chemistries (Strickland and Parsons, 1968).

Results-Nutrients

The results of all nutrient analyses completed to date are presented in Tables 147-150. Reactive nitrite and nitrate determinations were initially assessed separately but later were measured as a combined value. Analyses for ammonia, reactive silicate, and reactive phosphorus (Molybdate reactive dissolved inorganic) were always individually determined.

The nutrient data has been analyzed and summarized for each of the major sampling areas. Monthly average nutrient values (in microgram-atoms per liter) were determined for each of these areas.

Nitrate and Nitrite

Nitrate plus nitrite values in May ranged from 0.9-1.9 (mean 1.3) for the ocean stations, and from 0.3-1.0 (mean 0.5) in Little Egg Harbor. Single values for May in Little Egg Inlet and Brigantine were 0.8 and 0.5, respectively. No nutrient samples were taken during May in either Great Bay or the Mullica River. During June, combined nitrate and nitrite values for each of the major areas were as follows: ocean, 4.8-6.8 (mean 5.6); Little Egg Inlet, 0.4-2.0 (1.1); Great Bay, 0.2-1.8 (0.7); Mullica River, 0.3-2.9 (1.5); Little Egg Harbor, 0.3-1.6 (0.7); and Brigantine, 0.4-2.0 (1.0). Nitrate plus nitrite values for July were as follows: ocean 0.4-0.6 (mean 0.5); Little Egg Inlet, 0.5-1.6 (0.9); Great Bay, 0.3-1.4 (0.7); Mullica River, 1.6-3.5 (2.6); Little Egg Harbor, 0.3-1.3 (0.7); and Brigantine, 0.5 (0.5, two samples).

In summary, late spring mean values for these nutrients were the highest in the ocean and in the Mullica River (means>1.2). The other areas were fairly similar (means 0.5-1.1). The early summer mean value for the Mullica (2.6) was the only outstandingly high concentration. The remaining areas were relatively similar, ranging from means of 0.5 to 0.9.

Ammonia

Analyses for ammonia are available only for May and June. In May, ammonia values in the ocean ranged from 4.1-7.5 and averaged 5.7. Single values for Little Egg Inlet and Brigantine were 3.7 and 5.2, respectively. Little Egg Harbor values ranged from 3.1-5.3 (mean 4.1). No values for either Great Bay or the Mullica River were available for this month. During June values for ammonia were as follows: Little Egg Inlet, 2.3-7.4 (mean

4.9); Great Bay, 3.5-5.2 (4.2); Mullica River, 5.5-6.4 (5.9); Little Egg Harbor, 1.8-4.4 (3.2); and Brigantine, 1.9-7.1 (5.0). No values were available for the vicinity of the Site during June.

Most areas had fairly similar concentrations during May and June with a range of means of 3.2 to 5.9. Mean values in the ocean (5.7) and Mullica (5.9) were again the highest of all the areas.

Silicate

Silicate values for May ranged from 1.8 to 3.8 (mean 2.4) for the Site area, and from 1.5 to 2.1 (1.7) in Little Egg Harbor. Single values for Little Egg Inlet and Brigantine were 1.6 and 3.2, respectively. During the month of June silicate values were as follows: ocean, 8.3-10.0 (mean 9.2); Little Egg Inlet, 4.5-7.9 (6.6); Great Bay, 4.1-16.4 (10.9); Mullica River, 12.3-39.4 (24.4); Little Egg Harbor, 3.5-21.5 (9.9); and Brigantine, 2.4-15.5 (9.7). July values for silicate were as follows: ocean, 2.3-6.5 (mean 3.4); Little Egg Inlet, 2.2-7.7 (5.8); Great Bay, 5.1-26.8 (15.1); Mullica River, 28.1-45.7 (37.1); Little Egg Harbor, 3.2-27.4 (17.3); and Brigantine, 15.1-18.8 (17.0).

In summary, the results indicate that silicate concentrations increased during late spring in all areas (means of 1.6-2.4 in May to means of 6.6-24.4 in June). The highest value during this period (24.4) was for the Mullica. Early summer mean values were somewhat lower than late spring highs both in the vicinity of the Site and in Little Egg Inlet. The remaining areas, however, exhibited a further increase at this time, with the Mullica River again having the highest concentration (37.1).

Phosphate

Phosphate determinations in May for the Site area ranged from 0.5 to 1.3 (mean 1.0) and in Little Egg Harbor from 0.7 to 0.9 (0.8). Single values were recorded for Little Egg Inlet (1.0) and for Brigantine (1.1). June figures for each area were as follows: ocean, 1.9-2.6 (mean 2.1); Little Egg Inlet, 0.8-1.3 (1.0); Great Bay, 0.6-1.4 (1.0); Mullica River 0.4-1.0 (0.6); Little Egg Harbor, 0.4-1.9 (1.2); and Brigantine, 0.7-1.6 (1.2). July values for phosphate were as follows: ocean, 0.9-1.3 (mean 1.1); Little Egg Inlet, 1.1-1.4 (1.3); Great Bay, 0.9-1.7 (1.3); Mullica River, 0.5-1.4 (0.9); Little Egg Harbor, 1.4-2.1 (1.8); and Brigantine, 2.0-2.3 (2.1).

In summary, late spring mean values for this nutrient were fairly similar for most areas (means 0.8-2.1). The lowest concentration for this period occurred in the Mullica River (mean 0.6). Early summer mean values were similar to those of late spring for four of the areas (ocean, Little Egg Inlet, Great Bay, and Mullica River) but somewhat higher for the others (Little Egg Harbor and Brigantine).

Results-Phytoplankton and Protozoa

The major components of the ocean phytoplankton and protozoa in the present study were indicated from an examination of live sample aliquots from August through December, 1972. These preliminary results are presented in Table 151. They represent those forms noted in approximately two to four drops of subsample. Diatom classification to suborder followed Fritsch (1935). A variety of sources were used for further taxonomic subdivisions (see Table 151). The protozoa were classified according to Kudo (1971).

In samples from the vicinity of the Site the dominant group was the diatoms, numerous representatives of which were noted during each month. Species belonging to the genera Skeletonema (probably S. costatum), Nitzschia, and Rhizosolenia, in particular, were noted throughout the entire period. Various small centric forms were also prevalent. Dinoflagellates occurred with the next greatest frequency in the samples examined. They were especially well represented during August and September, with members of the Prorocentridae being particularly noteworthy. Both the diversity and abundance of these forms declined by winter. Various naked flagellates (both pigmented and colorless) were well represented throughout the entire period. Silicoflagellates, ciliates, sarcodines, and chlorophytes had only a scattered representation in the samples.

To date, preserved samples from a single station on one cruise have been enumerated. The samples were collected on 10 August at the Site from three depths. A minimum of two counts of each sample were made with both the Sedgwick-Rafter and Palmer-Maloney chambers. Abundance of organisms per unit volume was determined according to procedures outlined by Jackson and Williams (1962). Results (Table 152) indicate that the phytoplankton and protozoan communities were at that time characterized by a relatively high species diversity and by population densities similar to other coastal waters (see Smayda, 1973). In comparison with the examination of live samples, the enumeration of preserved samples indicated a preponderance of smaller forms.

The most important group numerically and probably also by biomass was the "naked flagellates" which had an average density for the three depths sampled of approximately 1.2 million cells/liter. In this category the most important forms numerically were the smaller (less than 6 microns) pigmented species followed by intermediate size (6-12 micron) species. It was not possible to satisfactorily recognize, and thus enumerate, the colorless flagellates in the preserved samples. Because these forms were not included the total count probably represents a very conservative estimate of the actual total.

Numerically the second most important group was small (2-3-micron diameter) chain and colony-forming cells tentatively identified as blue-green algae (Cyanophyta). Their overall average density was approximately 640,000 cells/liter. They were relatively unimportant to the total biomass because of their small size.

Numerically, the third most important group was the diatoms, which exhibited an overall average density of approximately 139,000 cells/liter. Because of their size they were probably the second most important group based on biomass. Rhizosolenia spp. (4-5 species noted from each depth) accounted for the majority of the diatoms present. As a group, small pennate species less than 30 microns in length were next in importance numerically. Approximately 14-17 species were noted from each depth. All other diatoms were essentially of minor importance in the total count.

None of the armored dinoflagellates were dominant at any of the depths examined and densities were low (less than 1,500 cells/liter) in all instances. Tintinnids and silioflagellates were also present at very low densities.

Discussion

A discussion of the "microbiota" which may occur in estuaries and their ecology was presented by Lackey (1967). He stated that the species composition of these groups in estuaries is dependent primarily upon the "chemical composition of the water," and secondarily on other parameters such as light and temperature. Nutrients analyzed to date in the present study from estuarine waters in close proximity to the Site indicate that these waters are an important nutrient reservoir.

Durand and Nadeau (1972) discussed the seasonal patterns in nutrient flux in the Great Bay-Mullica River estuary. According to these investigators phytoplankton production was influenced most by light and the concentration of available nitrogen. Their determination of primary production by measurements of both oxygen production in the summer (light-dark bottle method) and year-round chlorophyll a concentrations revealed the following:

1. Although compensation depths were generally similar in the Bay and River, the depth of the River was greater and thus the amount of phytoplankton production per unit area was much less.

2. On a per meter squared basis, primary production in the Bay was consistently greater than the respiratory requirements, but in the River it was lower.

3. Primary production (chlorophyll a concentrations) in both the River and Bay was generally highest in the summer and lowest in the winter. An exception to this was the occurrence of a peak in late winter (February and March) values at the mouth of the River.

4. The lowered productivity during the winter was attributed to a combination of lower temperatures and shorter days with lowered light intensities.

A limited comparison of nutrient data from this study with the findings of Durand and Nadeau (1972) for 1961-1962 are in close agreement. In both studies monthly means of nitrate-N and inorganic phosphate (microgram-atoms per liter) in the Great Bay-Mullica River estuary were made at comparable localities (Table 153).

According to Durand and Nadeau (1972) the main source of nitrogen and phosphorus for Great Bay is the Mullica River. Their study indicated that nitrate-N was generally the only nutrient which was ever limiting in the Great Bay-Mullica River estuary. This may be partially due to the much more rapid turnover rate for phosphorus as compared with nitrogen (Dawson, 1966; Durand and Nadeau, 1972; Pomeroy, et al., 1972; Riley, 1967). Since inorganic nitrogenous compounds are required for phytoplankton growth, a limitation in the availability of one or more of the nitrogen containing nutients is likely to be reflected in a decrease of the standing crop.

For relatively unpolluted to moderately polluted coastal waters from southern New England (Vineyard Sound) to Virginia (lower Chesapeake Bay) summer phytoplankton densities ranged from 50,000 to 400,000,000 cells/liter (Smayda, 1973). The summer phytoplankton densities in more polluted water such as the bays of south shore Long Island occasionally exceeded 10^9 cells/liter (ibid). The total mean density of phytoplankters enumerated in the present study was approximately 2 million cells/liter (Table 152).

ZOOPLANKTON

Phillip H. Sandine, Vincent J. McDermott, and J. Howard Chamblin, Jr.

Introduction

Zooplankton is the animal component of the plankton. Although planktonic organisms are those which drift passively with the currents, most zooplankters are capable of considerable locomotion. They utilize this capacity primarily in vertical rather than in horizontal movements, and this often results in distinct vertical stratifications.

The zooplankton is composed of two major groups. The holoplankters spend their entire life cycle as "drifting" organisms. The meroplankters consist of two subgroups: the planktonic larval stages of benthic invertebrates and fish; and the young and adults of some benthic invertebrates which temporarily become planktonic primarily to feed or reproduce.

Most zooplankton surveys have used plankton nets with mesh net apertures greater than 157 microns and thereby have collected mostly holoplankters, primarily copepods. Most meroplankton larvae and small holoplankters such as rotifers, tintinnids, and protozoa are not retained by such nets. During the first six months in 1972, zooplankton samples were collected in conjunction with the ichthyoplankton study. The net used had a mesh aperture of 500 microns. This net retained primarily macrozooplankters, adults of the larger copepods, and some meroplankton larval forms. From July through October, No. 8 (203 microns) and No. 10 (153 microns) nets were used. A No. 20 net (80 microns) has been used routinely since 20 November. This net retains most of the developmental stages of all copepods, most post-trochophore stage meroplankton larvae, and some of the smaller holoplankters.

Materials and Methods

Sampling Areas

In 1972, five zones in the vicinity of the Site were sampled twice a month as were most of the 13 bay stations. From July to November, ichthyoplankton and zooplankton cruises were combined, and two cruise days were needed to sample the bay stations. Separate cruises now allow all bay stations to be sampled in one day, and usually within 48 hours of an ocean cruise. Station descriptions are given in Table 93.

Field Procedure

During 1972 only surface tows were taken. By March of 1973, 5-minute surface, bottom, and oblique tows were taken at the Site using Clarke-Bumpus samplers equipped with No. 20 nets. If clogging was evident, a shorter tow time was used and additional hauls of 5 to 10 minutes were taken with No. 10 nets. Macrozooplankters were enumerated from surface, midwater, and bottom ichthyoplankton tows taken with 1-m and 0.5-m nets. All samples were preserved in 5% buffered formalin immediately after collection.

In the bays, only the Inlet and Mullica River stations will be routinely sampled with surface and bottom tows. Other procedures for the bay stations were as described above except that no oblique tows were taken.

Laboratory Procedure

Samples are first examined grossly for macrozooplankters. When these forms are abundant the sample is divided with a Folsom plankton splitter to facilitate enumeration. The zooplankton samples are then concentrated to a volume between 50 and 350 ml. This sample is thoroughly mixed and a 1-ml subsample is taken with a Stempel pipette. The subsample is placed in a Sedgwick-Rafter chamber and enumerated under a compound microscope. A minimum of two subsamples is taken per sample. Results for ocean and bay collections enumerated are presented in Appendix Tables 47 and 48.

Statistics

The Wilcoxon signed rank test was used to test the difference in densities of zooplankton between ocean stations seaward of the Ridge, at the Site, and in the Inlet from September through January. A Student's "t" test was used to test the difference in number of taxa collected at three bay stations: Mullica River, Great Bay No. 2, and the Inlet. A 0.05 level of significance was used in the tests.

Results and Discussion

Ocean Meroplankton

Approximately 80% of the benthic marine invertebrates inhabiting coastal waters possess a planktonic larval stage (Thorson, 1950). In temperate latitudes the reproductive period of the majority of these invertebrates is closely associated with the warmer months of the year (Kinne, 1970).

Benthic forms that occur in the plankton as adults include members of the Cumacea, Isopoda, Polychaeta, Amphipoda, and Caridea. Postmetamorphal bivalves also occur in the plankton (Williams and Porter, 1971). Of the bivalves found in the vicinity of the Site, *Solemya velum*, *Petricola pholadiformis*, *Ensis directus* and *Donax fossor* have postmetamorphal swimming ability and occur seasonally in the plankton. Postmetamorphal individuals of Tellina, Macoma, and Spisula should also occur randomly in the plankton throughout the year (ibid).

The concentrations of the various meroplankton groups from surface samples taken at the ocean stations from September through December, 1972, are given in Table 154. Species identifications have been hindered by the lack of adequate descriptions in the literature. The larvae of the common blue mussel (Mytilus edulis) were readily identified, however, and accounted for approximately 90% of the enumerated meroplankton during the fall.

The average number of meroplankton per m^3 obtained with a No. 20 net during the late fall was as follows: seaward of the Ridge, 792; Site, 848; and Inlet, 653. Meroplankton densities will probably be greater during spring and early summer, the period when most benthic invertebrates reproduce.

The significantly greater retention of meroplankton larvae by a No. 20 net relative to a No. 10 net is shown in Table 155. Nevertheless, enumeration values for these larval forms is decidedly conservative even with use of a No. 20 net. This is because many meroplankton larvae begin as free floating eggs, which first develop into soft-bodied trochophores, 100 microns or less in size. Such forms are often forced through a No. 20 net during a tow. Two days or more of growth are needed before many of these forms can be retained in numbers representative of their densities. During the first few days of development, however, most larvae are lost to predation.

Plankton nets used prior to September did not adequately retain most meroplankton larvae. Two forms, the megalops of the common rock crab (Cancer irroratus) and the fifth larval stage of the American lobster (Homarus americanus) were adequately retained. Both forms were most abundant in late June and early July (Table 156). During this period, rock crab megalops were taken at all ocean stations and most bay stations. American lobster larvae, although taken both in the ocean and the bays, occurred less frequently.

The American lobster, which is commercially important off the New Jersey coast, has an optimal hatching temperature of about 20 C (Hughes and Matthiessen, 1962). At this temperature the planktonic larval stage averages 14 days under laboratory conditions. An increase of 2 C above the optimum temperature shortens the planktonic stage to 9 days while a similar decrease will lengthen it to 28 days (ibid). Because this species broods its eggs and is relatively large, both as a larvae and adult, it generally has a low mortality rate when compared to other meroplankton forms. Consequently relatively few larvae are produced to maintain the population.

Saila and Pratt (1973) stated that Sastry (unpublished) found the optimal growth of common rock crab larvae occurred at 15 C. At temperatures above 20 C the larval metabolic rate was depressed.

Simultaneous surface and bottom tows taken during daylight in February and March, 1973, in the vicinity of the Site showed meroplankters to be concentrated at the bottom. This was also true for the total zooplankton concentration (Table 157). Results of a 14 month zooplankton survey in the New York Bight region showed that the greatest densities of meroplankton, bivalve and polychaete larvae, occurred in midwater and bottom samples. (National Marine Fisheries Service, 1972).

Common blue mussel larvae comprised some 90% of the meroplankton larvae taken during the fall. This species was rarely found in ocean benthic samples, although it was very common in the inlets. Kinne's (1970) review indicated that the blue mussel was primarily a spring spawner at temperatures of 10 to 16 C. Chanley and Andrews (1971), however, estimated that in the coastal waters of Virginia the blue mussel might spawn year-round. This species is limited in its distribution to waters where temperatures do not normally exceed 27 C.

Of the 23 common benthic invertebrates found in the vicinity of the Site (Table 158), 12 possess a planktonic larval stage, and 7 have juveniles or adults or both that are at times planktonic. Thus, at least 19 of the 23 common benthic forms are plankotnic during part of their life cycle.

The only commercially important species listed in Table 158 is the surf clam (Spisula solidissima). Off the New Jersey coast, surf clams have a major spawn in July and August and a minor one in the fall, although the fall spawn does not appear to occur annually (Ropes, 1968). The planktonic larval stage lasts 3 weeks or more (Carriker, 1967). The upper lethal limit for adult surf clams is between 26 and 28 C (Saila and Pratt, 1973).

Of the 12 common benthic invertebrates possessing a planktonic larval stage, 7 have a Boreal-Virginia distribution (Gosner, 1971). Maximum summer water temperature is apparently one factor that limits their southern distribution. The common rock crab inhabits shallow waters in the northern part of its range, but deeper, cooler water in the southern part. Of the seven common benthic invertebrates which are planktonic as juveniles or adults or both, three have a Boreal-Virginia distribution (ibid). Two of these, Neomysis americana and Crangon septemspinosa, are abundant in the vicinity of the Site.

Present knowledge of thermal tolerances for marine invertebrates is based primarily on laboratory work with adults and subadults (Kinne, 1970). It is also necessary to know the thermal tolerance of other life cycle stages, such as the gametes, fertilized egg, and early ontogenetic stages. It is these which appear to be most sensitive to temperature (see Bayne, 1965; Kinne, 1970; Sandine, 1973).

Ocean Holoplankton

A total of 67 surface tows from the Site area were examined from January through December, 1972. Data for 49 of these samples are given in Appendix Table 47. Copepods comprised the largest percentage (91%) of the enumerated zooplankton. Of the 13 species identified, Oithona similis, Centropages typicus, and Acartia tonsa occurred most frequently and in greatest numbers. Paracalanus parvus, Temora longicornis, Oithona brevicornis, Acartia clausi, and Labidocera aestiva were abundant seasonally. The remaining copepod forms were found occasionally and in small numbers. Other forms such as cladocera, pelagic tunicates, coelenterates, ctenophores, hydromedusae, chaetognaths, and pteropods were also taken (Table 159).

Although copepod forms (nauplii, copepodites, and adults) comprised the major constituents of the zooplankton surface samples, other holoplankters were at times common. Species which showed short-term peaks of abundance were the cladocerans, Evadne nordmanni, Penilia avirostris, and Podon spp. during the fall; pelagic tunicates (Oikopleura spp.), siphonophores, and hydromedusae during spring and fall; and ctenophores, particularly Mnemiopsis leidyi and Beroe sp. (probably B. ovata), during July and August.

From September through December, 1972, the mean density of copepods was 4,510/m^3 with a range of 105 to 17,446/m^3. Mean densities and horizontal distribution of copepods in the surface waters seaward of the Ridge, at the Site, and across the Inlet, indicated a general trend of increasing numbers with increasing distance from shore (Table 160). A signed rank test, however, indicated no significant difference between these stations. Simultaneous surface and bottom tows taken during daylight in

February and March, 1973, indicated a strong preference for subsurface water by copepods during that period (Table 157).

Information pertinent to some of the more abundant zooplankton is summarized below and in Table 161. Oithona similis, a small cyclopoid, comprised 27% of the zooplankton enumerated. Average mean density from September through December was $2,293/m^3$, with a range of 0 to $14,716/m^3$. Densities of O. similis in the study area increased with distance from shore. This species does not appear to reproduce at temperatures much above 20 C (Deevey, 1960).

Oithona spp. apparently prefer subsurface and bottom waters (National Marine Fisheries Service, 1972); thus, they were probably more numerous throughout the water column than was indicated by our surface samples. Oithona spp. comprised the major component of the zooplankton population in Block Island Sound (Deevey, 1952), and were the most numerous and frequently occurring copepods in the New York Bight region (National Marine Fisheries Service, 1972).

Centropages typicus, a common neritic form, was present in collections throughout most of the year. The average density for the fall was $785/m^3$, with a range of 0 to $5,093/m^3$. Results from September through December, 1972, indicated the average density of C. typicus also increased with distance from shore.

This species is considered to be primarily a surface form. It has been recorded at temperatures from 0 to 28 C, and breeds at temperatures from 1 to 25 C (Deevey, 1960). It is most abundant in salinities of 30 ppt or more. This species was the dominant zooplankter in the waters outside Delaware Bay (ibid), and was found consistently in the surface plankton of the continental shelf (Bigelow and Sears, 1939).

The preceding two forms may be considered year-round species. However, the majority of the copepods taken appear seasonally. These include the winter-spring forms, *Pseudocalanus minutus*, *T. longicornis* and *A. clausi*; and the summer-fall forms *A. tonsa*, *O. brevicornis*, and *L. aestiva*.

Acartia tonsa, a littoral species, was found in all samples taken from September through December. The average density during this period was $328/m^3$, with a range of $2\text{-}1{,}205/m^3$. *A. tonsa* was distributed rather uniformly at all stations in the surface waters near the Site. This euryhaline-eurythermal species occurs primarily in sheltered coastal waters and bays. *A. tonsa* has been reported to occur at temperatures from -0.7 to 32 C. The upper limit (32 C) is that of Florida populations. *A. tonsa* from Chesapeake Bay showed little or no reproduction at temperatures above 30 C (Heinle, 1969). Gonzalez (1972) found that populations of *A. tonsa*, when acclimated to temperatures between 25 and 27 C, tolerated temperatures as high as 37 C for several minutes.

Acartia clausi has been the subject of thermal tolerance studies (Gonzalez, 1972; Sandine, 1973). Results showed *A. clausi* to have a lower thermal tolerance than *A. tonsa*. *A. tonsa* begins to replace *A. clausi* in estuarine waters of New Jersey in June. There is some evidence that the thermal tolerance of natural populations of *A. clausi* is lowered when food is scarce (Sandine, 1973).

Pseudocalanus minutus, a boreal form, appears to be temperature sensitive. Anraku (1964) stated that this species appears to have an optimal temperature of 15 C or less and that temperatures much above 20 C may be lethal. Greatest densities of *P. minutus* taken in the study area to date ($1{,}000/m^3$) were from ocean bottom samples taken in February and March, 1973.

Deevey (1960), in a study of the waters inside and outside of Delaware Bay, found that *P. minutus* was more abundant and occurred for a longer period outside the Bay. During its occurrence temperatures did not exceed 23 C.

Ocean Macroplankton

Organisms classified as macroplankton are greater than 1 mm in size and represent those forms retained by a No. 000 net (1-mm mesh aperture). They are readily visible under gross examination. Data from the present study suggest that finer meshed nets may not adequately sample macroplankton. Therefore, in addition to the basic zooplankton sampling program, metered collections taken at the Site for ichthyoplankton are also being examined for macroplankton.

Sixteen surface, midwater, and bottom collections taken at ocean stations in the vicinity of the Site from 10 November 1972, through 13 March 1973, were examined for macroplankters (Appendix Table 49). Mysids, chaetognaths, and hydromedusae accounted for approximately 99% of the forms enumerated. Tunicates, ctenophores, cerianthiarian anemones, cumaceans, and tomopterids were present in low numbers.

Mysids constituted 75% of the forms enumerated. *Neomysis americana* was by far the dominant species within the group. *Mysidopsis* spp. were also taken, but in small numbers. The relative abundance of mysids collected during the macroplankton sampling period is biased by two bottom collections which together accounted for 85% of the total mysids. The largest number ($187/m^3$) was taken off Little Egg Inlet in a bottom water sample on 19 December, while the second highest density ($139/m^3$) occurred at the Site on 5 January in a bottom sample. These values are high when compared with a mean density of $2.49/m^3$ for all other collections in which mysids were taken. The only significant number of Neomysis taken in the upper water column coincided with the peak density in bottom water at the Inlet on 19 December and was probably related to the high turbidity (secchi of 1.5 ft) on that date. Hopkins (1965), in a study of mysid shrimp in the Indian River Inlet, Delaware, showed that these organisms avoided surface waters during daylight hours followed by the occurrence of large numbers at the surface at night.

Sagitta spp. ranked first in frequency of occurrence, second in order of abundance, and comprised 20% of all macroplankters collected. Four Sagitta species accounted for more than 90% of the macroplankters enumerated in surface and midwater samples. Peak density occurred on 16 January ($60/m^3$) but then declined to a minimum level in early March ($.02/m^3$). S. elegans was the dominant chaetognath; S. tenuis, S. enflata, and S. serratodentata were less common.

Density of Sagitta increased markedly with depth. During the sampling period the total density of arrow worms was $7.93/m^3$ at the surface, $49.06/m^3$ in midwater, and $141.77/m^3$ at the bottom. Spooner (1933) reported a positive phototaxis in arrow worms. Data from our collections (Appendix Table 49) indicated an avoidance of the brighter surface zone.

Hydrozoans were second in frequency of occurrence and third in abundance (3.3% of the collected macroplankters). Medusae were most abundant in the lower portion of the water column.

Obelia spp. made up 85% of all hydrozoans collected. Others in descending order of abundance included Margelopsis gibbesi, siphonophores, Rathkea octopunctata, Bougainvillae spp., and several unidentified hydromedusae. It may be that a significant number of these small sized (1-1.5 m) soft-bodied organisms were either not retained in the 0.5-mm mesh nets or were broken up.

The plant breakwater may provide a favorable substrate for the polypoid forms of these organisms which may lead to localized increases in the abundance of medusae in the plankton.

Oxyurostylis smithi, a bottom-dwelling cumacean of shallow coastal waters, was taken in eight collections. A boreal cumacean, *Leptocuma minor*, was found in bottom samples on 10 November 1972, and in mid-March, 1973.

Four isopod species taken were *Cirolana concharum*, *Chirodotea almyra*, *Idotea metallica*, and *Edotea triloba*.

Amphipods, particularly *Gammarus annulatus* and *Protohaustarius wigleyi* were taken in several midwater and bottom collections.

In summary, mysids and arrow worms comprised the bulk of the macroplankton biomass. Greater concentrations occurred near the bottom.

Results and Discussion-Bays

Enumeration of bay samples is incomplete. Data for those samples analyzed are presented in Appendix Table 48. Because all bay stations were not sampled on the same date, comparisons between stations are hindered. However, the Mullica River Station No. 2, Great Bay Station No. 2, and Little Egg Inlet were always sampled on the same date. These stations represent a typical estuarine salinity gradient. A total of six collections taken from the three stations from August through December is summarized in Table 162. These data indicate that the average density of total zooplankton was greatest at the Inlet Station and least at Great Bay Station No. 2. Mullica River values were somewhat less than those of the Inlet. Estimation of zooplankton at the other Great Bay stations (zones 1050 and 1070) is not complete but the indication is that these stations had a greater density of zooplankton than Great Bay Station No. 2. Durand and Nadeau (1972) reported highest concentrations of total zooplankton in the lower Mullica River and Great Bay and lowest near the Inlet over a 2-yer period. This differs from results in the present study although data here cover only five months. Williams, Murdock, and Thomas (1968) have also found a lack of agreement between successive short term zooplankton surveys conducted in an estuary.

Average number of taxa was significantly (P=0.05) greater in the Inlet than in the Mullica River (Table 162) probably because the Inlet receives both estuarine and ocean waters and their respective biological populations.

The high zooplankton densities in the Mullica were due primarily to a bloom of *Eurytemora affinis* in November and December. This species was noted at all bay stations except the Inlet station by late December.

The maximum density for a single species was for *Acartia clausi* adults and copepodites (32,255/m^3) collected in Little Egg Harbor on 29 December (Appendix Table 48). This species was not noted by Durand and Nadeau (1972), possibly because they did not differentiate *A. clausi* from *A. tonsa*.

Bays and Ocean Compared

Estimated average surface density of zooplankton obtained with a No. 10 net was 1,958/m^3 (N=25) in the ocean and 1,260/m^3 (N=20) in the bays. Average surface density with a No. 20 net was 18,731/m^3 (N=20) in the ocean and 6,401/ m^3 (N=24) in the bays.

The increased densities obtained with a No. 20 net at the ocean stations resulted primarily from a large increase in the retention of copepod nauplii, individuals of *Oithona* spp. and bivalve larvae. *Oithona* spp. accounted for 7.5% of the total zooplankton obtained with a No. 10 net, but 34% with a No. 20 net. For the bay samples taken with a No. 20 net, *Oithona* spp. represented only 4.5% of the total zooplankton. The increase noted in bay samples obtained with a No. 20 net was primarily due to copepod nauplii. In addition, the blooms of *Eurytemora affinis* and *Acartia clausi* occurred when a No. 20 net was in use in the bays.

All species of copepods noted in the bays also occurred in the vicinity of the Site except for *Eurytemora affinis*. Only the euryhaline species, *Acartia tonsa* and *A. clausi* were found at all bay and ocean stations. *A. tonsa* collected from September through December averaged $325/m^3$ per ocean station and $467/m^3$ per bay station. The monthly average of *A. tonsa* remained fairly constant in the ocean but declined in the bays through the fall. *A. clausi* steadily increased in numbers both in the ocean and bays during November and December. Average density per station (November and December) for *A. clausi* was $310/m^3$ in the ocean and $2,147/m^3$ in the bays. *A. clausi* accounted for some 30% of the total bay zooplankton from August through December.

Other common holoplankters which occurred both in the vicinity of the Site and bays were hydromedusae, ctenophores, and cladocerans. The cladocerans, however, were found only at bay stations where salinities exceeded 20 ppt. A list of species and their densities for all samples enumerated is given in Appendix Tables 47 and 48.

MARINE ALGAE

Richard P. Smith

Benthic algae have been collected and classified since September, 1972, from the bays and the ocean in the vicinity of the Site.

Specimens have been collected on a qualitative basis either by seine, hand, or trawl. Scuba diving or snorkeling is a better method of collecting in some areas and will be utilized in the future.

A representative specimen of each species collected was dried and mounted using a Ward's standard botanical plant press. Liquid preservation can cause cellular destruction and, therefore, was not used.

Little information is available on the marine flora of southern New Jersey bays and estuaries. Qualitative and quantitative data were compiled for Barnegat Bay by Moeller (1964) and Loveland et al. (1970 and 1972). Marine algae found in these two studies are listed in Table 163; those from the present study in Table 164. All algae were identified according to Dawson (1956) and Taylor (1957). Specimens were examined alive before mounting on herbarium paper for future reference.

Codium fragile was collected occasionally by trawl in the vicinity of the Site. At times large amounts were washed ashore at Cedar Run (Seine Station 11) in Little Egg Harbor.

Codium fragile is a Pacific coast species which was accidentally introduced to the New York area and has spread rapidly southward. It was the tenth most abundant marine alga in Barnegat Bay from 1965 to 1968. In 1969, it was third and from 1970 to 1972 it was the most abundant species (Loveland et al., 1972). In Barnegat Bay, Codium has increased and generally replaced Champia parvula, Enteromorpha intestinalis, and Enteromorpha linza (Loveland et al., 1970).

Codium prefers a hard substrate for attachment. It grows very rapidly in dense stands and crowds out other species of algae and invertebrates which seek a similar substrate. Shells are an ideal substrate for Codium and it has become a nuisance on the clam beds of Barnegat Bay and Little Egg Harbor. Codium has not reached the Great Bay-Mullica River estuary but it could become a serious problem if it becomes established on the clam and oyster beds there. This species was collected off Beach Haven Inlet in trawl samples and could become a common attached form on the proposed breakwater at the Site.

Gracilaria foliifera is a red alga which seems to be common in the bays near the Site. In Barnegat Bay this alga and Codium are dominant (Loveland et al., 1972). Gracilaria is commercially harvested off North Carolina but is not harvested in this area. Agar is the chief extract from this species and has a wide variety of uses.

Agardhiella tenera is another dominant red alga taken by trawl in all the bays.

Two species of Polysiphonia (P. nigrescens and P. fibrillosa) have been collected in the intertidal zone. Polysiphonia nigrescens has been found occasionally at various seine stations in Little Egg Harbor. It is particularly common on the gravel substrate found at Graveling Point in Great Bay. This species has also been found growing on shell hash. This alga ranked eighth of 128 major species collected in Barnegat Bay from 1965 to 1968. From

1969 to 1970 it was not a major species for Barnegat Bay (Loveland et al., 1970) presumably due to competition from Codium.

Polysiphonia fibrillosa seemed to be more common than P. nigrescens. Although it was usually found at intertidal levels, it occasionally was taken in trawl collections in the bays.

Porphyra umbilicalis is a red alga resembling Ulva in its general morphology. It is found commonly on rocks and pilings in Brigantine. This alga was not collected until January, 1973, and is predominantly a cold water species. It is another species which may be found on the proposed breakwater at the Site.

Gymnogongrus griffithsiae is a marine alga which was taken occasionally in the Mullica River. All specimens collected of this species were washed ashore at Clark's Landing. Salinities in this area ranged from 0 to 11.5 ppt indicating that this alga favors brackish conditions. Gymnogongrus was found in August and September but was absent since October. Little is known of this alga's peculiar reproductive adaptations and modifications (Dawson, 1966).

Ascophyllum nodosum was found drifting near the Site. It belongs to the family of brown algae known as rockweeds of which Fucus is also a member. The rockweeds are associated with rocky coasts and are abundant in New England. Ascophyllum grows at intertidal levels and can withstand strong wave turbulence. A suitable habitat for this alga's attachment in this area is a rock jetty.

Three genera of algae have not been identified to species but have been observed in shore zones of Brigantine, Great Bay, and Little Egg Harbor. Fucus sp. is a common rockweed in these areas. It is of commercial value but it is not harvested locally. It is often found growing on ribbed mussels on marsh banks. Ulva sp. is an abundant alga in all areas. At times it covers extensive areas on the bottom of the bays. It is an important food source for the wintering brant population. Entermorpha sp. is an intertidal green alga common in all local bays and estuaries. It is also an abundant alga in most local tidepools.

TERRESTRIAL STUDY

Mark A. Pokras and Martha L. Pokras

Introduction

The terrestrial study was begun in June, 1972. A preliminary vegetational survey was conducted in the area of Great Bay Boulevard. Studies were made to determine the abundance, distribution, and food habits of common animal species. Information on small mammal populations was gathered through a trapping program and an analysis of owl pellets. Data on birds were obtained by a roadside census, from the files of the Brigantine National Wildlife Refuge, and from the files of the New Jersey Departments of Health and Environmental Protection. Reptiles and amphibians were collected. Records were kept of birds, turtles, and marine mammals seen offshore.

The study area extends from Manahawkin south to Atlantic City, and from the barrier beaches at least 1 mile onto the mainland. To date, most work has been conducted between Absecon and Tuckerton as the major habitat types in this small area are generally representative of the study area.

Vegetation

Vegetation studies during 1972 were conducted primarily in the area of Great Bay Boulevard in Tuckerton and the results are presented below.

Infrared aerial photographs of marsh and upland areas in the vicinity of Tuckerton were obtained from the New Jersey Department of Environmental Protection.

Each map covers an area of 1000 x 1000 ft. All tidal vegetation types 5 acres or more in extent are delineated. These maps will be used to determine the distribution of major plant species. Transect and quadrat studies will be conducted to determine the structure of the plant communities.

The three major habitats of the greatest acreage in the study area are the upland forest or Pine Barrens, barrier beach, and salt marsh. The upland region is characterized by pitch pine (Pinus rigida) and various oaks (Quercus spp.) Swamps are present along rivers and streams. Dominant swamp vegetation includes the Atlantic white cedar (Chamaecyparis thyoides), red maple (Acer rubrum), magnolia (Magnolia virginiana), and black gum (Nyssa sylvatica). The Pine Barrens extend from Asbury Park to the area of Woodbine, New Jersey and from the coast as far inland as Clementon and Browns Mills (Harshberger, 1916). This area has been a center for ecological research since the early part of this century and has many distinctive plant and animal populations (McCormick, 1970).

The barrier beach habitat once extended over much of New Jersey's eastern most fringe. It is an area of shifting sand colonized by hardy vegetation with high resistance to wind and salt spray. The barrier beach protects the marshes from the high winds and seas of ocean storms. Some dune plants have widespread root systems while others form mats that grow over the surface of the sand. These help stabilize the beach. Seaside goldenrod (Solidago sempervirens) and dune grass (Ammophila breviligulata) grow on higher portions of the beach face. Black bayberry (Myrica pensylvanica), and beach plum (Prunus maritima) grow in sheltered areas behind the first row of dunes.

The salt marsh extends along the coast between the upland areas and the barrier beaches. The occurrence of marsh vegetation types is determined largely by the frequency of tidal flooding. Salt marsh cordgrass (Spartina alterniflora - tall form) occurs in areas flooded twice daily. As the frequency of tidal flooding decreases, the tall form of cordgrass is replaced by the short form. The short form is succeeded by salt meadow cordgrass (Spartina patens), salt grass (Distichlis spicata), and marsh-elder (Iva frutescens).

Ten percent of all New Jersey salt marshes drain into the Mullica River and Great Bay (Durand and Nadeau, 1972). In a study of a section of salt marsh at Nacote Creek, Port Republic, New Jersey (Table 165), Durand and Nadeau (1972) reported that Spartina alterniflora (tall) composed 2.1% of the marsh. Preliminary estimates by Ichthyological Associates indicated that it composed a minimum of 15% of the marshes around Great Bay Boulevard.

Odum and de la Cruz (1967) reported that only a small percentage of Spartina alterniflora (tall) is utilized for food while it is alive. However, it transports significant quantities of phosphorus from the sediment to its leaves (Reimold, 1972) and is an important source of detritus. Due to concentrations of bacteria which form on the surfaces of this detritus the protein content may be four times as high as that of the live grass. Massmann (1971) stated that gammarid amphipods, copepods, cladocerans, isopods, crabs, clams, oysters, and other filter feeders may ingest this detritus. The bacterial layer of protein is absorbed by the filter feeder and the Spartina particle is evacuated. The particles may be recolonized by bacteria, consumed, and evacuated an many as six times before being totally digested (Massmann, 1971).

Small benthic algae grow over much of the marsh surface and on submerged macrophytes. Pomeroy (1959) found that up to one third of the total annual primary productivity of a Georgia salt marsh could be attributed to these algae and that they maintained their productivity throughout the year.

Reptiles and Amphibians

Eight amphibian and 12 reptile species collected or sighted during 1972 appear in Table 166.

A more systematic program for collecting reptiles and amphibians will begin during the spring of 1973. This will include a seine and minnow trap program to collect larval and adult amphibians.

One of the most common reptiles in the study area is the diamondback terrapin. It has been sighted in freshwater streams and beyond the surf zone in the ocean. It is most common, however, in bays and brackish tidal creeks. During the summer, females dig nests in high sandy ground where the eggs are protected from tidal flooding. Predators such as raccoons and skunks often eat the eggs, and many hatchling turtles are taken by gulls, crows, herons, and large mammals.

The box turtle is also abundant in the study area. This omnivorous reptile is almost completely terrestrial in habit. It is found throughout the study area in pine-oak woods, old fields, and bogs. A mark and recapture program is planned during 1973 to determine the local population size and home range of individuals.

Sea turtles are the only reptiles which occur at the Site. They are warm water species which move into the study area during summer and early fall. At least 10 turtles were sighted locally during the summer and early fall of 1972, four of which were the Atlantic loggerhead. This turtle generally breeds only as far north as North Carolina (Conant, 1958), but during the summer of 1972 one female nested at Ocean City, New Jersey. An Atlantic leatherback was seen in the vicinity of the Site on 25 September 1972. This sea turtle breeds in the tropics but may wander as far north as Nova Scotia.

About three years ago, a live Atlantic green turtle was found on a jetty in the surf at Ventnor. It weighed 5 lb. and was in good condition. This species occasionally strays as far north as Massachusetts (Conant, 1958).

It is possible that sea turtles might increase in number around the Site where warmer water and increased algal growth could provide a favorable habitat.

Birds

The coastal plain of southern New Jersey supports rich and diverse bird populations. The seasonal occurrence and relative abundance of 275 local bird species appears in Table 167. Additional species observed from Atlantic City to Manahawkin in 1972 appear in Table 168.

The study area may be divided into three ornithological regions (Fables, 1955). The Pine Barrens, or upland area, is composed of dry oak-pine forest and wet cedar swamps. Towhees, Carolina chickadees, pine warblers, and whip-poor-wills are common in the dry woods; catbirds and yellowthroats in the swamps. The salt and brackish marshes that extend along the New Jersey coast west of the barrier beaches are important feeding areas for herons, raptors, and waterfowl. Birds breeding in the marshes include clapper rails, willets, sharp-tailed sparrows, and seaside sparrows. A fringe of barrier beaches extends along the coast of New Jersey. Much of this region has been greatly altered by man. Original breeding species have been forced to find undisturbed islands or more remote beaches. Breeding species include oystercatchers, common and least terns, and black skimmers.

The offshore area constitutes a fourth ornithological region. Pelagic bird species that occur almost exclusively offshore include the gannet and Wilson's petrel. Sea ducks such as scoters and oldsquaw are common offshore in the winter.

Bird species hunted regularly in New Jersey include the Canada goose, brant, ducks, grouse, quail, pheasant, clapper rail, and woodcock. Ducks, geese, brant, and rails are taken in greater numbers in Ocean and Atlantic counties than elsewhere in New Jersey. In the 1970-71 season, game harvest on all species except woodcock increased (New Jersey Department of Environmental Protection, 1971). Season bag per hunter of 8 game bird species is included in Table 169. The number of hunters in Atlantic and Ocean counties is presented in Table 170.

A roadside census for measuring the relative abundance of local bird species was begun in September, 1972. Four car routes were selected to cover all major plant communities. A different route was surveyed each week during the month. Each census route was begun exactly 1/2 hour before sunrise, and continued for exactly 4 hours. The same two individuals participated each week, and both the driver and record-keeper served as observers. Every bird seen or heard was enumerated. The car was driven at about 5 miles per hour, and was stopped at frequent intervals. This made it possible to hear bird calls without interference from car noise.

The first census route through Tuckerton, includes 5.5 miles of salt marsh bordered by low scrubby vegetation along Great Bay Boulevard, 5.1 miles of residential neighborhood, and about 2 miles of upland oak-pine forest adjacent to the boulevard. The total distance covered is about 12 miles.

The second census route through West Creek, Tuckerton, and New Gretna, includes 2.2 miles of residential neighborhood, and about 12 miles of upland oak-pine forest. Part of this route passes through Bass River State Forest and part (1.6 miles) passes along a salt marsh of the Mullica River. The total distance is about 16 miles.

The third census route includes 8 miles along the dike system in Brigantine National Wildlife Refuge. This waterfowl management area includes fresh water marsh, brackish marsh, and open salt water. One mile of residential neighborhood and about 1 mile of upland oak-pine forest are also included for a total of about 10 miles.

The fourth census route through Absecon, Pomona, and Brigantine, is composed of 5.5 miles of residential neighborhood, about 4 miles of upland oak-pine forest, 0.8 miles of salt marsh, and 4.5 miles of barrier beach for a total of about 15 miles.

Combined, the mileage for these routes includes 4.5 miles of barrier beach, 7.9 miles of salt marsh bordered by low scrubby vegetation, 13.8 miles of residential neighborhood, 8 miles of a waterfowl management area, and approximately 18 miles of upland oak-pine forest. Also included along the census routes are a 67 acre fresh water lake, a number of fresh water ponds, fresh water streams, and small swampy areas with typical lowland vegetation.

Upland areas dominated by pitch pines and scrub oaks were, in general, depauperate. There was very little "edge" where birds might concentrate. Where streams or swamps interrupted the typical pine barrens vegetation, the variety and numbers of birds increased.

During the warmer months the marshes and the barrier beach supported large numbers of individuals and species. In the winter the number of individuals and species was low and gulls predominated.

Residential neighborhoods varied in the type of bird populations they supported. Species such as robins and mockingbirds forage on lawns, and were commonly seen throughout the warmer months. Open fields, plowed land, and second growth forests attracted a variety of species throughout the year.

From September, 1972 to 9 February 1973, the largest number of species (102) was counted between 29 September and 20 October (Table 171). This was largely due to migrants passing through the study area. The largest number of individuals (14,202+) was counted between 26 October and 17 November when large numbers of waterfowl were present. The smallest number of species (57) and individuals (7,088+) was counted between 22 December and 12 January.

Census totals are useful for an overview of the bird populations present. They indicate the minimum number of individuals of a species in the census area. Yearly trends in population levels, especially for non-flocking species, can be gleaned from annual census data (Howell, 1951).

Additional information on local bird populations has been gathered from other sources. In June, 1972, preliminary surveys were made of two active heronries in Little Egg Harbor. Although dense vegetation prevented access to the Barrel Island heronry, the number of adults counted and nests seen from the periphery indicated about 175 nests of 7 species (Table 172). Scattered vegetation on Goosebar Sedge permitted entrance to the heronry. A total of 51 nests of 5 species was found. An effort will be made during the summer of 1973 to locate additional heronries in the study area.

Dredging and filling of marsh along with widespread building has eliminated numerous breeding areas for herons. An active heronry that was located on the south end of Brigantine Island has been destroyed by construction in that area. The number of birds breeding in the unprotected Margate heronry is decreasing as filling and construction increase (James Akers, personal communication). Those heronries still active are being monitored by local conservation groups and Ichthyological Associates' personnel to detect any changes in population levels.

Brigantine National Wildlife Refuge is a federally operated waterfowl management area. Most of its 18,111 acres are within a 10 mile radius of the Site. Use of the refuge by bird species appears in Tables 173 to 176.

Waterfowl were present throughout the year (Table 177) although highest concentrations occurred in the fall. Over 500 young Canada geese and 2,625 young ducks were produced at the refuge during 1971. Use of the refuge by water and marsh birds was limited during the winter months (Table 178). Heavy concentrations occurred between May and August. Fifteen hundred young clapper rails were produced in 1971.

Shorebirds were seen at the refuge throughout the year (Table 179). Huge flocks occurred regularly during spring and fall migration. Breeding species included the oystercatcher, woodcock, and willet. Laughing gulls and terns were most common during the summer (Table 180). In 1971, 18,000 young laughing gulls were produced. Most herring gulls and great black-backed gulls breed to the north. They appeared at the refuge in increased numbers in the fall. Three hundred and fifty black skimmer young were counted.

Brigantine Refuge was utilized throughout the year by many species of endangered raptors (Table 180). Five pairs of osprey nested within the refuge in 1972, although no viable young were produced. Peregrine falcons and Cooper's hawks, as well as other falcons and accipiters, passed through the refuge during fall migration. Bald and golden eagles were seen regularly at the refuge during the winters of 1971-1972 and 1972-1973.

Many species are taken by mist-nests, including inconspicuous ones which are often missed by census techniques. Data on local bird-netting over a 9-year period were made available by Dr. William C. Carter of the New Jersey

State Department of Health (Table 181). Between 1961 and 1969, mist nets were set in five woodland areas throughout the state. Methods and materials are described in Kerlin and Sussman (1963). One station was near Oceanville in a woodland area of the Brigantine National Wildlife Refuge. A total of 12,602 specimens of 125 species were taken there during 327 trapping days. Longevity data obtained from recaptured individuals during the state netting program are presented in Table 182. A white-eyed vireo and an ovenbird were recaptured 7 years after initial capture. Four other species had individuals at least 6 years old, and six species had individuals 5 years or older.

Mr. Fred Ferrigno of the New Jersey Division of Fish, Game and Shell Fisheries, Department of Environmental Protection, made available the results of the annual New Jersey Aerial Waterfowl Inventory. The New Jersey coast and bays were censused from the air five times or more each year, and waterfowl populations enumerated. Data beginning with the winter of 1968-1969 appear in Tables 183 to 187. Summary data for the entire Atlantic Flyway were also provided for the years 1970 (Table 188) and 1972 (Table 189).

The following descriptions of the status of waterfowl species in New Jersey are based on Tables 173 to 176, and Tables 183 to 189. Food habits are based on Bent (1925) unless otherwise specified.

Canada goose

The Canada goose, a popular game species, is present in the study area throughout the year. Less than 1% (4,100) of the Canada geese utilizing the Atlantic Flyway during 1972 wintered in New Jersey. Heaviest concentrations, however, occurred in Delaware, Maryland, and Virginia, where over 80% of the 700,200 individuals wintered. Between Longport and Manahawkin 3,000 geese were counted in October, 1971. Brigantine Refuge is a favored wintering area. In the spring of 1971 breeding geese produced 510 young in the refuge. Canada geese feed on the marshes, where they eat sedges, grasses, and some animal material.

Brant

The brant, a goose that breeds in the Arctic, winters along the Atlantic coast. The 1972 winter survey indicated that 66.3% of all Atlantic Flyway brant were in New Jersey. It is most common in bays and inlets, but is occasionally seen offshore. Large concentrations of brant occur between Barnegat Light and Atlantic City, where in past years there has often been an adequate supply of food consisting of sea lettuce (Ulva lactuca) and eelgrass (Zostera marina). Between Longport and Manahawkin, heaviest concentrations were typically in the Reed Bay and Lakes Bay area. A small number of brant was recorded in Brigantine Refuge throughout the summer. The number of brant has fluctuated greatly over the last 20 years (Table 190). In 1960, the New Jersey wintering population reached a high of 194,800. In 1970, 129,400 brant were counted while in December, 1972, there were only 18,450 along the New Jersey coast. The reasons for the decline are not fully understood. The 1972 breeding season produced almost no young. This was attributed to the fact that the breeding areas in the tundra did not thaw as usual during the spring. It has been hypothesized that a decrease in the amount of sea lettuce (Ulva) along the Atlantic coast may have also contributed to their general decline (Robert Burgoon, personal communication). As a result of this decline, the 1972 hunting season for brant was cancelled.

Mallard

The number of mallards (186,600) counted along the Atlantic Flyway in the winter of 1972 was 19.2% lower than in 1971, and 9.5% lower than the

10-year average. In 1972, 4.3% (8,000) of the Atlantic Flyway total wintered in New Jersey. Between Longport and Manahawkin 5,500 mallards were counted in December, 1971, and more than half of these were within Brigantine Refuge. In 1971, 200 young were produced on the refuge. About 90% of the food taken by the mallard is vegetable material, including sedges, grasses, and smartweed. Animal material taken includes insects, crustaceans, and mollusks.

Black duck

The 1972 winter survey of Atlantic Flyway waterfowl indicated that 30.3% (81,700) of the black ducks were in New Jersey. This was a greater percentage than in any other Atlantic coast state. In January, 1972, 44,000 black ducks were counted between Longport and Manahawkin, more than 50% of which were within Brigantine Refuge. Black ducks breed throughout the Northeast and North Central states. In Brigantine Refuge 400 young were produced in the spring of 1971. In the winter, black ducks feed on the marshes, where they eat snails, bivalves, crustaceans, and some vegetable material. In the summer they feed in ponds and swamps on aquatic insects and larvae, amphibians, worms, seeds, and roots of aquatic and land plants.

Gadwall

The total number of gadwall (15,000) counted along the Atlantic Flyway in the winter of 1972 was 42.7% lower than the 10-year average. Only 1.3% (200) of the total wintered in New Jersey. Large numbers pass through New Jersey on their fall migration to more southerly wintering grounds. A total of 2,500 gadwall were counted in September, 1971, between Longport and Manahawkin. Ninety-six percent of these were within Brigantine Refuge. Although most gadwall breed in the Northwest, 1,550 young were produced in Brigantine Refuge in the spring of 1971. Vegetable material such as pondweed, sedges, and algae may comprise as much as 97% of the food taken by gadwall.

Pintail

The 1972 winter waterfowl survey of the Atlantic Flyway indicated that 1.5% (1,600) of the pintail were in New Jersey. The total (107,800) was 16.9% lower than the 10-year average. Pintails pass through the study area in large numbers in late fall. In November, 1971, 8,000 were counted between Longport and Manahawkin, all of which were within Brigantine Refuge. The pintail breeds in the Northwest, but individuals appear again in the study area in August. Vegetable material such as pondweed, sedges, grasses, and smartweeds may comprise more than 80% of its food. Animal food taken includes mollusks, crustaceans, and insects.

Green-winged teal

The 1972 winter survey of Atlantic Flyway waterfowl indicated that 4% (3,100) of the total number of green-winged teal occurred in New Jersey. In late fall, however, 13,000-15,000 individuals were counted from Longport to Manahawkin. Over 60% of these were in Brigantine Refuge. A few were observed in the refuge throughout the year, although most fly north in the spring to breed. Sedges, pondweeds, grasses, and other vegetation make up about 90% of their diet. Insects, mollusks, and crustaceans comprise a minor portion of the diet.

Blue-winged teal

The number of blue-winged teal counted along the Atlantic Flyway during the winter of 1972 (6,400) was 58.7% lower than the 10-year average for the species. None were counted in New Jersey. During September, 1971, 7,400 were observed between Longport and Manahawkin. Ninety-four percent were within Brigantine Refuge. Although most breeding is limited to the prairie states, 450 young were produced in Brigantine Refuge in the spring of 1971. Vegetable material such as sedges, pondweeds, grasses, and smartweeds make up

75% of the diet. Animal material taken includes mollusks, insects, and crustaceans.

American widgeon

The 1972 winter waterfowl survey indicated that 3.4% (2,400) of Atlantic Flyway widgeon were in New Jersey. The total of 71,500 was 28.4% below the 10-year average, but indicated a 7.2% increase over 1971. American widgeon are common locally in late fall. In 1971, 4,200 were counted between Longport and Manahawkin and more than 50% of these were in Brigantine Refuge. Vegetable material, including pondweeds, grasses, algae, and sedges may make up as much as 93% of the diet of the widgeon. Animal food is comprised almost entirely of mollusks.

Shoveler

The number of shovelers counted along the Atlantic Flyway in the winter of 1972 (10,500) was 42.6% lower than the 10-year average. Some 4.8% (500) of these were in New Jersey. A census in November, 1971, indicated that all 2,000 present between Longport and Manahawkin were in Brigantine Refuge. In the spring of 1971, 15 young were produced in the refuge. The shoveler feeds on grasses, duckweeds, small fish, small frogs, shrimp, worms, and insects.

Scaups

Scaups were the most numerous species counted along the Atlantic Flyway in the winter of 1972. This count probably included both the greater and lesser scaups which are difficult to distinguish from the air. Greater scaup are more common on salt water. Some 4.5% (19,300) of the total were in New Jersey. Most of the scaups seen between Longport and Manahawkin were in Little Egg Harbor. Scaups migrate northwest in the spring to breed in Canada and Alsaka, and are not seen in the study area until late August. They feed on crustaceans, starfish, and mollusks while wintering along the coast. Vegetable material taken includes the seeds of eel grass.

Common Goldeneye

The 1972 winter waterfowl survey indicated that 4.4% (2,400) of the common goldeneye along the Atlantic Flyway were in New Jersey. Goldeneye arrive in the study area in late fall. More than 50% of the individuals counted between Longport and Manahawkin were in Little Egg Harbor. They winter along the coast and feed on small mussels and other mollusks. They also eat eel grass seeds, aquatic plants, and some insects. It is possible that the aerial counts may include a few individuals of Barrow's goldeneye, which is an uncommon species in the East.

Bufflehead

The number of bufflehead counted along the Atlantic Flyway in the winter of 1972 (46,700) was 15% higher than the 10-year average and 51.6% higher than the 1971 count. In 1972, 18.4% of the total (8,600) were in New Jersey. In January, 1972, 5,000 individuals were counted between Longport and Manahawkin. Bufflehead were absent from the study area from May to October. During the winter they feed predominantly on small fish, small shellfish, and crustaceans.

Oldsquaw

The number of oldsquaw counted along the Atlantic Flyway in the winter of 1972 (25,000) was 220.5% higher than the 10-year average, and 115.5% higher than the number counted in 1971. Some 6% or 1,500 of these were in New Jersey. Between Longport and Manahawkin, 800 individuals were counted in January, 1972. More than 60% of these were in Little Egg Harbor. The oldsquaw dives to obtain mollusks, which make up the bulk of its diet. It also feeds along the beaches where it takes crustaceans, small mollusks, and seaweed. Oldsquaw migrate at night (Robbins, Brunn, and Zim, 1966).

Surfscoter, White-winged scoter, common scoter

The 1972 winter waterfowl survey indicated that 31.8% (47,300) of the total number of scoters along the Atlantic Flyway were in New Jersey. In December of 1971, 40,000 scoters were counted from Longport to Manahawkin. Seventy-five percent of these were in the area of Lakes Bay and Scull Bay. Scoters appear in the study area in October, and depart in March or April to breed in Canada and Alaska. They fly in long strings low over the water during migration. Mollusks (clams, oysters, and mussels) comprise about 75% of the diet of white-winged scoters, and 60-65% of the diet of the surf and common scoters (Kortright, 1942). Crustaceans, fish, and plant material form a minor portion of their diet (Martin, Zim, and Nelson, 1951).

A program to determine the food habits of local scoter populations was begun in October, 1972. Specimens of common and white-winged scoters were obtained from local hunters. The crops, gizzards, and stomachs of 24 birds obtained in late October were examined. No food material was found, although shell hash and grit were sometimes present. The shell hash included fragments of clams and mussels.

Coot

The 1972 winter waterfowl survey indicated that only 0.2% (700) of the coots along the Atlantic Flyway were in New Jersey. Most coots winter farther south along the Atlantic coast. In November, 1971, all 2,500 coots counted between Longport and Manahawkin were within Brigantine Refuge.

Fifty young were produced within the refuge in 1971. Its food consists mainly of vegetable material, including wild celery, foxtail grass, and algae.

Many species of birds migrate over the vicinity of the Site. An understanding of the migratory habits of these species is necessary in considering the potential effect of the plant structure. Some migrants may use the plant structure and breakwater as a resting area. Under certain conditions birds may collide with the plant.

The following groups of birds migrate by day: hawks, doves, swifts, swallows, crows and jays, robins and bluebirds, and blackbirds and orioles. Nocturnal migrants include rails, woodcock, spotted sandpiper, woodpeckers, and most passerine species such as flycatchers, nuthatches, creepers, some thrushes, vireos, warblers, and finches (Van Tyne and Berger, 1959). Waterfowl and most shorebirds migrate by day or night.

Season, wind, and weather all affect the migratory patterns of birds. The average altitude of migration is 1,500 to 2,500 ft above the ocean (Griffin, 1964). Altitude of migration is generally lower in fall than in spring. When the sky is clear, birds may fly higher than average. During a heavy overcast, birds often migrate at reduced altitude. Birds flying into a strong headwind may fly low over the water. Layton (1969) reported that purple martins fly very near the surface of the water. Moreau (1938) reported that buntings, doves, and pipits, when faced with a headwind during migration, flew within 5 to 30 ft of the surface of the Mediterranean. The common scoter and oldsquaw averaged 300-1,000 ft over the water during their spring passage over the Gulf of Finland (Bergman and Donner, 1964).

Many birds migrate down the Atlantic coast in the fall, and a large number of these either migrate over the ocean or are blown there by heavy north or northwest winds. Some of these birds pass in the vicinity of the Site. Stone (1937) reported that large numbers of robins, woodcock, and warblers came into South Cape May from the open ocean. Some warblers, flickers, kinglets, and creepers landed on Ichthyological Associates' boats at the Site during the fall of 1972. Young (1972) reported that when he traveled 8 miles east of Pt. Pleasant Beach, New Jersey he counted 30 birds which landed on the boat. He identified sparrows, kinglets, finches, starlings, and an osprey. This occurred in October after 2 days of dense fog. It is likely that the plant structure and breakwater will serve as a resting place for many diurnal migrants.

Migrating birds may be attracted to strong light beams illuminating tall buildings, lighthouses, or towers. The approaching birds are attracted to the brightness, become blinded, and fly into the light, the supporting structure, or the ground (Pettingill, 1970). Large kills of a variety of species have occurred at such structures during nights of heavy migration (Vosburgh, 1966). Lighting systems can be modified to minimize their effect on migrating birds.

The following species have been observed offshore in the vicinity of the Site.

Scoters and oldsquaw are common in the vicinity of the Site in winter. Their status has been discussed above.

The horned grebe is seen frequently during the winter both in the bays and ocean. Large numbers were seen flying south near the Site in December, 1972. Grebes feed underwater on fish, crustaceans, and other small animals.

The common loon winters along the Atlantic coast. It has been sighted in the bays and ocean. It will dive to feed on fish, crustaceans, and some water plants (Robbins et al., 1966). This species, and a few red-throated loons, were observed migrating in the vicinity of the Site during early December, 1972.

Wilson's petrel nests on islands in the south Atlantic. They begin migrating north in March, and from June to September are abundant off the Atlantic coast of the United States. These birds are pelagic and feed primarily on small fish, shrimp, and other planktonic animals.

The gannet is a pelagic bird which winters in the study area. It is most abundant in late fall and in April during migration. Gannets feed in the ocean and have been seen in the vicinity of the Site. Their food consists almost entirely of fish.

The three most common gulls along the New Jersey coast are the herring gull, laughing gull, and great black-backed gull. The herring gull and great black-backed gull are predominantly scavengers. The laughing gull feeds primarily on fish.

Laughing and herring gulls breed in the study area. While the herring gull is a permanent resident, the laughing gull winters to the south. The great black-backed gull goes north in the spring to breed, but is common in local bays and the ocean in fall and winter. Bonaparte's gull is common around local inlets in the winter. It feeds on small fish and crustaceans near the water's surface. Gulls are often abundant in the ocean, particularly over feeding schools of bluefish, striped bass, and weakfish. Here they pick up injured and fragmented bait fishes.

The common tern is abundant in the study area in spring and summer. It winters farther south. Terns feed by diving into the water to catch small fish. Most feeding is restricted to inshore areas, but common terns have been seen feeding in the vicinity of the Site.

The royal tern passes through the study area in the fall. Although it roosts on the outer beaches, it may feed far offshore. It was frequently seen by Ichthyological Associates' crews offshore from September to November.

Many of the birds which occur offshore may be directly affected by the presence and operation of the proposed plant. Any concentration of small fish in the vicinity of the Site will tend to attract gulls, terns, loons, and grebes. Scoters and oldsquaw might concentrate in the vicinity of the Site if mollusks are common on the breakwater.

Mammals

Information on mammals in the area was obtained from trapping, roadkills, and visual sightings. Sightings of large mammals were recorded. A list of all mammal species identified by sighting or taken by traps appears in Table 191. A reference collection of mammal skins and skulls is being prepared from species obtained by trapping or those found dead. When possible dead specimens are sexed and measured, and their stomach contents analysed.

A trapping program for small mammals was begun in June, 1972. Snap traps and Sherman live traps were baited with cracked corn, or peanut butter mixed with oatmeal. To date, 135 small mammals of 10 species have been trapped (Table 192). Preliminary data indicate that the meadow vole is the most abundant small mammal in local salt marshes. The white-footed mouse, pine vole, and short-tailed shrew are widespread in upland areas. Sixty of the 135 small mammals trapped were Peromyscus, 52 of which were identified as P. leucopus (the white-footed mouse). The red-backed vole was found only in white cedar swamps, but may also appear in sphagnum bogs. The meadow jumping mouse was taken only from an open field adjoining a salt marsh.

From 29 August to 7 September, 1972, a semiquantitative small mammal trapping program was conducted in the vicinity of Tuckerton, New Jersey. Two plots, each of 1.1 acres, were sampled. Thirty-six Sherman live traps were placed in a uniform 6 by 6 grid with 15 yards between traps. Cracked corn was used as bait. Cotton was placed in each trap to help insulate trapped animals overnight and insure greater survival.

One plot was in a mature oak-pine forest 150 yards southwest of Holly Lake in Tuckerton. The other plot was in an old field on the west side of Great Bay Boulevard in Tuckerton about 500 yards south of Holly Lake. Trapping data (Table 192) were analyzed according to Smith (1966) and used to compare the two areas. Population estimates (per acre) in the pine-oak forest were as follows: white-footed mouse, 14.5; short-tailed shrew, 5.5; pine vole, 3.5; chipmunk, 3.5; and red squirrel, 1.5. The same species were present in the old field. Population estimates there were as follows: white-footed mouse, 16; short-tailed shrew, 4; pine vole, 10.5; chipmunk, 3.5; and red squirrel, 1.5. Pine voles appear to be more abundant in the old field.

Future trapping in wet bog localities may confirm the presence of the masked shrew and southern bog lemming. Trapping in fresh and brackish meadows along the larger rivers and streams may document the presence of the least shrew. Efforts will be made to collect the rice rat which was hypothesized to occur in local marshes (Ulmer, 1951).

In July, 1972 an abandoned barn owl nest was found on Little Beach. Twenty whole regurgitated pellets and numerous pellet fragments were collected from it. In August an active barn owl roost was found in Absecon. Pellets have been collected periodically from this roost since mid-August. Analysis of the pellets will reveal the owl's feeding habits and possibly the presence of mammals in the area which trapping might miss. Those pellets examined indicated that the meadow vole made up a major portion of the diet. Rats, birds, and other mammals were also eaten.

Large mammals are wider ranging in their habits and therefore cannot be associated as closely with specific vegetational areas as small mammals. The river otter, an endangered species, occurs at the Brigantine Refuge. Infrequent observations of this species were made by Ichthyological Associates' personnel in Little Egg Harbor behind Long Beach Island and in Nacote Creek at Port Republic.

Deer, squirrels, and rabbits are hunted each year in New Jersey. Harvest of all species increased in the 1970-71 season (New Jersey Department of Environmental Protection, 1971), although the number of hunters for each species in Atlantic and Ocean Counties decreased from 1969-70 to 1970-71 (Table 170).

Marine mammals have been sighted in the study area on numerous occasions. In many cases positive identification was impossible. Known sighting are included in the following species accounts.

The harbor seal is a species which occurs regularly in the study area during winter. It is more common in harbors and bays than in the ocean, and has been sighted in Little Egg Inlet, Little Sheepshead Creek, and Little Egg Harbor behind Beach Haven. The harbor seal feeds on fish, crustaceans, and mollusks. Most breed on the New England and Canadian coast.

The Atlantic bottlenose dolphin has been described as the most abundant cetacean along the New Jersey shore (Ulmer, 1961). It is common in spring and summer, but departs in the fall to breed in warmer waters. A few, however, overwinter (Ulmer, 1961). Two probable sightings of this species occurred in early fall. One was close to the Site; the second was about 6 miles to the south.

The Atlantic harbor porpoise is common as far south as Cape May, New Jersey. It is usually seen along the Atlantic coast in large groups. Two porpoises seen were tentatively identified as this species. Food consists of herring, mackerel, whiting, small salmon, eels, squid, and crustaceans (Hall and Kelson, 1959).

The presence and operation of the proposed plant may affect the seasonal occurrence and local abundance of marine mammals. Concentrations of fish may attract dolphins, porpoises, and seals. It is possible that warmer water may extend the seasonal occurrence of some species.

A list of marine mammals reported off the New Jersey coast (H. Winn, personal communication) is presented in Table 193. Ulmer (1961) provided additional information on New Jersey's marine mammals. The common finback whale is common off New Jersey. Since 1929 at least 14 strandings and innumerable sightings have been recorded. The sperm whale and right whale generally occur in oceanic waters but are occasionally stranded on shore.

On 3 January 1973, a rare beaked whale washed up on Long Beach Island. It was observed over a two day period by numerous scientists but died after being transferred to the New York Aquarium a few days later. It is thought to be an immature specimen of <u>Mesoplodon densirostris</u>, the

Atlantic beaked whale. Little is known of the biology of beaked whales. They apparently travel in pods and feed on cuttlefish.

GREAT BAY BOULEVARD

Particular emphasis has been placed on defining the communities present in the vicinity of Great Bay Boulevard, Tuckerton. This road extends five miles onto a peninsula which separates Great Bay from Little Egg Harbor. It provides a unique opportunity for the study of marsh ecology and wetlands succession.

Physiography

The Boulevard is located on a peninsula between Great Bay on the southwest and Little Egg Harbor on the northeast (Fig. 24). The road extends the length of the peninsula.

Near the mainland the road is 27-ft wide. The wooden bridges along the route are narrow, and have a maximum width of 12 ft 9 inches. Between the northerly two bridges the road narrows to 26 ft 9 inches and south of the third bridge the width is 21 ft.

The road has existed for at least 40 years. Trees and shrubs have grown along its borders and now provide a peninsula of upland vegetation which extends into the marsh. This wooded area in the marsh provides refuge for animals during times of high water accompanying storms and serves as a feeding and nesting area for many animals.

Vegetation

In the tidal salt marsh (Fig. 24, Area A), salt marsh cordgrass dominates and glasswort is common where the former has been disturbed. Salt meadow cordgrass is found just above mean high water.

Two major types of vegetation occur along the road (Fig. 24, Area B). The low area close to the marsh is dominated by bayberry, groundsel, seaside goldenrod, and various grasses. The higher ground adjacent to the bridges and toward the north end of the marsh is characterized by black cherry, white cedar, poison ivy, and honeysuckle. In areas of intermediate elevation, mixtures of the two types occur.

The old field area (Fig. 24, Area C) was formerly cultivated but is now densely covered by low grasses and herbaceous plants. Honeysuckle is a major ground species. Black cherry, choke cherry, red cedar, white cedar, and groves of sassafras are scattered throughout the area. The trees vary from 5 to 10 ft in height. On the western perimeter the field grades into a forest dominated by pine, holly, and greenbrier.

In the pine-oak forest (Fig. 24, Area D) the major canopy trees are pitch pine, post oak, and black oak. Holly is a major sub-canopy component. The dense understory is dominated by greenbrier, honeysuckle, sweet pepperbush, and small oaks.

In the fresh water marsh (Fig. 24, Area E) the dominant flora is semiaquatic reeds and grasses such as cattail and bur-reed. Hydrophilic trees such as red maple and black gum are common at the edge of the marsh.

The barrier beach type (Fig. 24, Area F) of vegetation includes the glassworts, saltwort, sea-bite, and the sea-rocket, which grow on the sand above the high tide level. They meet and intermingle with seaside goldenrod, evening primrose, and beach grass on the dunes.

The plant species present in the zones described above and their relative abundance are indicated in Table 194.

The vegetation along the Boulevard is important to local animal populations throughout the year. This high area along the road is used for nesting and feeding by many species. The vegetation serves as an important refuge from extreme high tides and winter ice. A variety of animals utilize this area because the vegetation is in an intermediate successional stage. Such a stage has the greatest diversity of plant species and provides the maximum number of niches for animals to occupy. Early successional stages in the area are dominated by the reed Phragmites. This stage is usually stable and of limited use to many local birds and mammals.

Animal Life

The diamond-back terrapin is the only reptile found in the brackish waters of the area. It is common and nests on the higher land along the Boulevard. Reptiles and amphibians found in nearby upland and fresh water areas are listed in Table 195.

The Boulevard supports large and diverse bird populations. Land birds and upland game birds concentrate in the scrubby vegetation along the road. Waterfowl, wading birds, and shorebirds utilize the adjacent marsh. Birds observed in the vicinity of the Boulevard and their seasonal occurrence are given in Table 196. Results of monthly 4-hour censuses of the marsh and the adjacent upland area over 6 months are reported in Table 197.

The marsh near the Boulevard supports a large breeding population of the clapper rail. Each fall, the largest concentration of rail hunters to be found from Barnegat Light to Cape May Point occurs here (Mangold, 1971). Black ducks, mallards, and geese are common and hunting pressure is heavy.

The marsh provides food and cover for resident and migrant waterfowl throughout the year. Many ducks enter the marsh from surrounding bays each night to find cover. The marsh along the Boulevard is the primary feeding area for hundreds of herons and egrets that nest each year on the islands in Little Egg Harbor. The yellow-crowned night heron, which appears on the New Jersey list of endangered and rare species, often feeds in the marsh.

Ring-necked pheasant, bobwhite, and ruffed grouse have been seen along the road and may breed in nearby upland areas. Many birds modify their route during their migrations and follow the roadside where they utilize the cover and food (Baird and Nesbit, 1960).

Raptors occur along Great Bay Boulevard throughout the year. A wintering population of marsh hawks feeds on rodents and small birds in the area. The sparrow hawk, pigeon hawk, and the peregrine falcon have been observed in this area during their migrations. In 1972, one pair of osprey nested in the Great Bay Boulevard marsh. Osprey which nest both north and south of the area feed in the marsh.

The meadow vole is the most abundant small mammal in the salt marsh near the Boulevard. In upland areas the white-footed mouse, pine vole, and chipmunk dominate. Mammals which are known to occur near the Boulevard are listed in Table 198. Those which have been taken by small mammal traps are included in Table 199.

On 20 December 1972, the marsh on the west (Great Bay) side of the road was flooded while the east (Little Egg Harbor) side remained dry. As the tide rose, water crossed over the Boulevard from west to east. At high tide the water was 2.5 ft deep on the road in some areas. Only the trees and shrubs along the road remained above water. Many specimens of the meadow vole and some of the Norway rat were seen in the roadside vegetation. An estimated 6 to 10 meadow voles were present per 100 ft of road. Birds observed feeding on the rodents included two short-eared owls, six marsh hawks, great blue herons, great black-backed gulls, and many herring gulls. Large numbers of American bitterns, snowy and common egrets, and a few Louisiana herons were also noted and may have fed on the meadow voles. The latter is one of the major components of the marsh food chain. This is especially true for wintering predatory birds and larger mammals such as foxes. The large vole population depends partly on the availability of high land which provides a refuge during high tide and serves as a winter forage area.

Discussion

Both the Pine Barrens and the salt marsh are characterized by having relatively few plant species dominant over large areas. The number of animal species is correspondingly low. The vegetational composition of the Pine Barrens is determined by factors such as frequency of fire, drainage patterns, and acidity of soil and water (McCormick, 1970). The marsh vegetation is determined by altitude, frequency of tidal inundation, and sedimentation. Changes in any of these major environmental factors may alter the entire structure of the community.

Clearing and building have destroyed many of the southern New Jersey's natural areas. This has resulted in a significant increase in some populations that were stable in the past. Herring gulls are now pests throughout much of the East. Other species are disappearing. Bald eagles used to breed in many parts of the state. Their numbers have been continually decreasing and at present only a few are sighted locally, predominantly in the winter. Pesticides and habitat destruction have contributed to this decline. The New Jersey Wetlands Act was designed to prevent further destruction of the marshes. Legislation is pending to preserve portions of the Pine Barrens, large tracts of which are still in a natural state.

Little Beach, the easternmost part of Brigantine National Wildlife Refuge, is a barrier beach that has been subjected to minimal disturbance. It has been proposed that this area be protected as a wilderness area. Typical barrier beach vegetation and animals occur there which have been eliminated from numerous other areas along the coast.

Information is being gathered from both natural and disturbed areas and may make it possible to document and predict future changes in the area due to a variety of man's activities.

ACKNOWLEDGEMENTS

Many people have assisted us throughout the study. We wish to thank Paul E. Hamer, Principle Fisheries Biologist at the Nacote Creek Research Station, and his staff for their continued cooperation and help.

Charter-boat Captains Kenny Wilson of the Valiant II and Howard Weber of the Melody II, of Oyster Creek, New Jersey, are thanked for use of their boats and gear for a variety of collecting and for their extensive advice and help throughout the year. Much of the sampling was made possible and more efficient due to their assistance.

We thank the following for providing us with information regarding sport and commercial fisheries statistics: Starn's Marina, McGarrigel's Wholesale Fish Market, and New Jersey Fisheries in Atlantic City; Pat Arnao, Proprietor of Sea Horse Pier, Brigantine; and Nick Cotov, gill net and pot fisherman at Beach Haven, Long Beach Island.

Numerous people were helpful to our terrestrial ecology study. The staff of the Brigantine Wildlife Refuge provided access to their large data files and gave generously of their time. Dr. William C. Carter of the New Jersey State Department of Health provided data on bird-netting. Fred Ferrigno, Senior Wildlife Biologist, New Jersey Division of Fish, Game, and Shellfisheries, made available eight years data on wintering waterfowl populations along the New Jersey coast. Donald S. Heintzelman, Curator of Ornithology, New Jersey State Museum, provided access to the research facilities of the Science Department of the New Jersey State Museum. Dr. Roger Conant, Director and Curator of Reptiles, Philadelphia Zoological Garden, provided information on local reptiles and amphibians and suggested methods for collecting them. James Akers, a local ornithologist on Brigantine Island, provided information on local heron populations. The staff of Ocean World at Steel Pier, Atlantic City, provided information on sightings of marine mammals and reptiles.

Joseph Price, Director of the New Jersey Bureau of Shellfisheries, and Dr. Harold H. Haskins, Rutgers University, provided information on shellfish. Carol M. Lalli, Marine Science Center, McGill University of Montreal, Canada, identified gymnosomatous pteropods. John T. Hughes of the Massachusetts State Lobster Hatchery and Research Station, identified lobster larvae.

We appreciate the help of numerous personnel at the Sandy Hook Marine Laboratory, Highlands, New Jersey. In particular we wish to thank Ann B. Frame, Biological Technician, for her identification of amphipods and Wally G. Smith for his identification of fish larvae.

Special thanks are due to Dr. Susan C. Williams for her nutrient analyses of water samples.

We gratefully acknowledge the Stockton State College Library staff, particularly Carol Burkley, for their help in obtaining a wide variety of published materials.

Some members of our own staff who did not write sections of this report contributed invaluably to the success of the study.

Linda N. Dill and Joanne B. Rosenberg, secretaries, typed the major portion of the paper. We also thank Agnes M. Kirby and Anne L. Baker, part-time secretaries, for their help.

Funds were made available through Public Service Electric and Gas Company of New Jersey.

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